IMPROVISATION AS A STRATEGY FOR THE TEACHING OF PHYSICAL SCIENCE IN VENDA WITH REFERENCE TO TEACHER TRAINING

by

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DECLARATION BY CANDIDATE

I declare that "Improvisation as a Strategy for the Teaching of Physical Science in Venda with Reference to Teacher Training" is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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ABSTRACT

Practical work forms an integral part of physical science. Most schools in Venda have no laboratories for practical work. Teachers use the telling method. Students learn by rote. They learn without understanding science concepts. They cannot apply their knowledge to real life situations.

This research investigates the use of equipment from inexpensive material in teaching physical science. Teachers trained to improvise equipment use them in classroom teaching. These help teachers to understand many science concepts and use the process approach in their teaching.

The research found that when science is taught through experiments with improvised apparatus, student learning occurs at various domains of science education. The bad effects of lack of facilities for practical work are mostly eliminated. Meaningful learning leads to the understanding of science concepts. Students construct their own knowledge, apply it to any situation and enjoy learning the subject.

TITLE OF DISSERTATION:

IMPROVISATION AS A STRATEGY FOR THE TEACHING OF PHYSICAL SCIENCE IN VENDA WITH REFERENCE TO TEACHER TRAINING.

KEY TERMS :

Improvisation; teacher-training; science teaching; pre-service and in-service training; science teaching strategy; home-made equipment in science teaching; science teaching with simple equipment; meaningful science education; student-centred learning; project work in science; scientist-teachers to teacher-technicians; science learning at various domains.

DEDICATION

I hereby humbly dedicate this to my late parents who instilled the value of education and gave everything of their best for me to be what I am today.

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I wish to take this opportunity to express my sincere appreciation for, and gratitude to, all those who helped me in completing this project. In particular, I am greatly indebted to the following:

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NOTES ON SPECIAL LANGUAGE USAGE

1. **<u>The third Person Singular Personal Pronoun</u>**
   In references to "STUDENT", 'TEACHER" OR 'LECTURER', the pronoun HE (or its various "cases" - HIM, HIS, HIMSELF) refers to both the masculine and feminine genders.

2. ***The term STUDENT is used in the following discussion to refer to learners at all levels of education - elementary, secondary and tertiary.***

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CHAPTER 1

ORIENTATIVE INTRODUCTION

1.1 FACTORS LEADING TO THE STUDY

1.1.1 UNDERSTANDING SCIENCE

One of the broad definitions of science considers the subject as "knowledge, especially knowledge gained through experience" (Reader's Digest Great Illustrated Dictionary 1984: 1504). While pursuing knowledge, especially in science, one is always searching for explanations for changes and in so doing search for truth and reality. Chalmers, quoting Popper, says: "What we attempt in science is to describe and (as far as possible) explain reality" (Chalmers 1980: 159). Reality may manifest itself in several ways. "... In mathematics, for instance, reality is studied from a numerical and spatial angle, in physical science (physics and chemistry), from a kinematic (movement) and physical (energy in operation) angle and in biology from a biotic and psychic angle" (Dreckmeyr 1988: 13). In seeking the kinematic and physical aspects of objects and phenomena, one has to devise several measures; for example, using mathematics if it is quantitative measure, or analysis if it is qualitative measure, and so on. That means, physical science, though concerned with kinematic and physical aspects of reality, has to consider several other aspects of reality. This is because any single discipline cannot be studied in isolation: the division or segregation of disciplines into distinct unrelated subjects is rather artificial.

In the real world, there is interaction and mutual communication taking place between various disciplines at any one time. As a result, different subjects do not remain isolated;

they are related and linked to one another. Teachers need to be aware of this during their teaching, look for, and point out, such relationship among different subjects wherever possible. This is one reason why it is said that a teacher can play several roles at any time. For example, a science teacher does not only teach science, but also English (which is the medium of instruction), geography, history, mathematics, biology, and even guidance, whenever the teacher has an opportunity to teach these, while teaching mainly science. By so doing, the subject being taught becomes more meaningful and relevant to the students.

Along with this, one should also consider another important principle of teaching science. The subject should be taught in such a way that, whenever possible, the student is guided to perceive its application and practice. That means when physical science is taught, it should be linked to real life situations wherever possible. The contribution of science to the advancement of technology should be brought out. Science is undoubtedly an integral part of modern day living. Its basic understanding is essential for one to be considered literate today, as illustrated by Kahn & Rollnick (1993: 269-270):

> In biology micro-organisms would be studied for the relevance to understanding water related diseases; to purify water requires application of chemistry, and to distribute water, an understanding of physics. Looking at the science associated with transport brings in a host of areas: combustion chemistry, metal physics, the physiology of trauma. Better still, science can be linked to geography (road networks, distribution of produce), economics (costs and benefits), art (design), statistics (road accidents), indeed a whole school day's work.

This is a reason for making science compulsory in schools up to a point in many countries. The importance of science to daily life must also be made clear to those offering science so that they could understand the significance of studying the subject. Levy (1992: 46), in her address at a symposium on Science Education in South Africa, expresses similar sentiments when she observes that

> ...the processes whereby children learn necessitate that they be allowed to make sense of any incoming knowledge in terms of their own life experience. ...the cornerstone here is that no learning whatsoever takes place unless the students are allowed to ENGAGE with the knowledge and make sense of it in terms of their previous knowledge and experience.

Klopfer & Champagne (1990: 135) considers the function of science today in bringing literacy in science that includes "...not only knowledge of key scientific ideas, but also understanding the everyday applications of science and its ramifications in a technological age." Once students are made aware of the usefulness of science education, they start learning science with desire and willingness. The subject becomes meaningful to them. Under such circumstances they reap the benefit of their science education whether they are among the few going on into tertiary education or the many who leave the formal system of education to enter the 'world of work'. This is perhaps one of the reasons for countries like the United Kingdom recently formulating new science curricula with similar emphasis on the 'sciences for all' approach. To make this happen, as Kahn & Rollnick (1993: 262) points out, it will be necessary to "...broaden access to science education for the whole community" and this can only be achieved by bringing in free and compulsory education for all.

This principle of showing the usefulness of a subject is not only true of sciences, but of all subjects. Any subject must be linked as far as possible to real life situations. In other words, any subject must serve a purpose and that must be made quite clear to the students. That means a subject should be meaningful. For a subject to be meaningful to students, it is not enough for them to know just the content or subject matter. They should see the useful purposes that will be served by studying the subject. A teacher who tries to expand on this will naturally be talking to his students on some form of guidance as well. That means the purpose of the subject to life and real life situations should be clear. Knowledge of the subject, especially in the case of science, will only be meaningful if that knowledge is gained through experience. This is because of the nature of science. Science is a doing subject. It is developed on the basis of cause and effect that involves experimentation to try to find solutions to problems. That is, science tries to find by actual experiments the cause for an observed effect. Such effects are those 'unusual' changes we notice from time to time around us. For such a change to have occurred, scientists argue that there must have been some cause. Science accepts cause and effect and the investigations of science are built on such cause and effect. This makes science a subject that is concerned with investigations. To find the cause for a change, scientists have to conduct experiments, which involve scientific investigations. This means that the findings of science are built on investigation. The findings of scientific investigations, therefore, form the theory. Thus in studying science, one cannot divorce the processes of investigation from the end-products, which is the theory of science. Science can be meaningfully learnt if this is understood and the scientific method is applied in its study. That means content in science should be learnt by doing and observing wherever possible. This helps the students to understand the processes involved and thus gain the necessary experience to function as scientists.

To study science, it is necessary to develop certain skills that form part of the processes involved in DOING science. It is by being involved in the experience of *doing* science that the student will eventually 'know' science. This sentiment is expressed in Glover's observation that "...this discipline called SCIENCE can only be appreciated and its essential processes assimilated by the pupils DOING appropriate practical work" (Glover 1987: 39). Doing the appropriate practical work enables the student to get an insight into the concepts of science and learn the processes of arriving at the expected understanding. The involvement in such processes enables students to develop thinking, reasoning and problem-solving skills. They learn to reflect on problems and use practical skills to master content. By doing such activities they find the subject meaningful. They will then be in a position to apply the scientific principles and knowledge to daily life situations whenever the need arises. Learning science this way helps students who are less fortunate and who drop out of school to seek employment in the world of work because their knowledge of science is based on a sound foundation. Science education would have made them literate in science and equipped them with the basic understanding of not only the content of science but also the methods that could be employed to arrive at the findings of science. This will make the student better in any field of work because they would have been "...taught to think intelligently and critically; to be able to solve problems creatively and become innovative and inventive" (Levy 1992: 47). Science learnt this way will certainly be of tremendous help to the fortunate few who can continue with their tertiary education. Bridging or preparatory courses will not be necessary in such cases. Such students would have understood and internalised the basic concepts in science. They have obtained science education with understanding and insight. Their scientific concepts have been internalised. Besides, they have had opportunities to think and function as budding scientists. Process approach to science and the scientific methods employed will not be new to them. Such science education would have served its purpose: making them literate in science and equipping them with not only the content of science, but also the methods that are employed to arrive at the findings of science. Klopfer & Champagne (1990: 135) make a similar point thus:

> The most important function of science education in schools is the development of the kind of literacy in science for everyone, whether the students are headed towards science-related careers or especially if they are not. Today, this literacy in science includes, not only knowledge of key scientific ideas, but also UNDERSTANDING the everyday applications of science and its ramifications in a technological age. ...literacy is also a requisite for today's citizens in a democracy to participate intelligently in the formulation of public policies regarding the many issues which involve science and technology.

1.1.2 METHODS USED FOR TEACHING SCIENCE

Education is "initiation into worthwhile activities"(Moeletsi 1994: 61) quoting Peters, (1964). This could take place in different ways.

In an informal educational situation, this happens during casual contacts with elders and peers. As a result, knowledge of the culture and values of the society are acquired during the socialization process in a community into which a person is born.

In the formal educational situation, knowledge that is acquired with values, norms, attitudes and culture is primarily acquired in organised institutions of learning, such as schools and colleges. It is passed on from the teacher to the student, and methods differ according to different teachers and different situations.

One of the commonest methods used by teachers is the telling method. Students are told facts - the contents of the subject matter. This goes hand-in-hand with the total dependence on specific textbooks, sometimes on only one textbook as the sole source and reference material. In such situations, students are conditioned to learn without question and in many circumstances without even understanding what they are learning. They accept the teacher's word as the 'gospel truth' because it is firmly believed "...that knowledge is transmitted from the expert to the one who is ignorant..." (Levy 1992: 46). This leads naturally to rote-learning.

Education is based on mutual trust. However, teachers should instil in their students the habit of questioning and critical thinking. This is not because students should not trust what the teacher teaches or what the book has in print; it is meant to encourage the habit of independent, critical thinking. This is the basic training in scientific investigations. Without an enquiring mind, students are simply made to memorize facts presented by the teacher or the textbooks, often without understanding. The textbooks are syllabus-bound and do not usually encourage students' curiosity and challenge individual explorations. This poses problems for students who must cope with advancement in science with the passage of time. Levy aptly remarks, "Experience tells us that science is not absolute, immutable, infallible knowledge, untainted by human subjective experience... yet we teach science as a fixed closed body of knowledge" (Levy 1992: 45). This is happening in schools, as the researcher has had the occasion to observe, while supervising teacher-trainees during teaching practice in schools in Venda. These teacher-trainees follow the footsteps of their teachers, who taught them that way at school. It has been observed that teachers, more so than students, resist changes brought to the curriculum and methodology of teaching.

The question that must therefore be asked at this stage is: how should science be taught? To answer this question, we need, first, to look at the nature of science. Science has two components: one is the knowledge or the subject matter, which is the content that students are supposed to master; the other is the manner in which such knowledge is acquired. An important part of science is concerned with solving problems. In order to solve problems, it is necessary to follow certain accepted patterns of investigation. Such investigations are characteristic of science and are collectively called the processes of science. To learn science, it is necessary to use the investigative processes that form part of the method employed to solve problems in science. The nature and process of science require an investigative approach - the accepted scientific methods that include discovery, experimentation, collection of evidence and data, making generalizations, formulating a hypothesis based on data collected, verifying results to make sure that they are consistent, and establishing laws. Such scientific methods were not used extensively and satisfactorily for teaching science even in the first world countries till about the late fifties. The realisation of the need for this method led to the development of the Nuffield Combined Science Project in Britain and the several different approaches and versions to the study of chemistry, physics, and biology in America in the fifties and the sixties (for example, Physical Science Study Committee [PSSC], 1956; Chemical Education Material Study

[CHEM study], 1959; and Biological Sciences Curriculum Studies [BSCS], 1963). More recent trends of linking science, technology and society and making science relevant to all rather than to selected few who are academically able to cope with further education has led to the recent development of the Science and Technology in Society (SATIS) and the Salters Programmes in the United Kingdom. Given the great strides science education has made in other countries, it is time to make science education more germane and meaningful to our students in the schools in Venda.

The method of teaching science by using the textbook without understanding and by rote-learning goes well with the culture of learning that occurs in Venda. According to their culture, young people and all students are supposed to respect teachers and all elders. They are not supposed to question the authority and wisdom of the teacher. Students therefore are used to following all the instructions given by the teachers without asking any questions at all. Though it cannot be denied that discipline should go hand-in-hand with education, it must be also noted that education is not a one-way process. It should be a democratic, healthy, two-way process, and there should be interaction in both directions between the educator and the educand. Chaudhari comments as follows on the relationship between science and democracy:

> In no other form of government science-education is more essential than in democracy. As a matter of fact science and democracy draw inspiration and support from each other. Science plays fair with the facts while democracy plays fair with the individuals. Science enlightens democracy and democracy humanizes science. Science cannot be segregated from democracy without the danger of partial starvation (Chaudhari 1986: 115).

1.1.3 FACTORS CONTRIBUTING TO THE LACK OF INTEREST IN THE STUDY OF PHYSICAL SCIENCE

Concerning the teaching of natural sciences and mathematics, it is acknowledged that there is " a lack of interest among pupils in physical science as a school subject..." (HSRC 1981: 8). Figure 1.1 (Du Plessis, Du Pisani & Plekker 1990: 16) provides a statistical picture for the entire Black standard ten pupil population in different subjects. From this figure, it can be seen that in 1989 only 17,9% of pupils were enrolled for physical science, whereas 28,5% were enrolled for mathematics and 89,0% for biology.

Extensive research was done in the early eighties into the teaching of physical science, biology, and mathematics at secondary schools for Whites in the RSA and SWA/Namibia at the request of the Scientific Advisory Council of the Prime Minister by Swanepoel, (1982: XXXIV) because of "a noticeable decrease in the percentage of White pupils who studied physical science and mathematics at secondary school level during the early seventies..." From this it appears that the lack of interest in physical science both in the White and the Black population groups over the years in South Africa has been generally a universal phenomenon. In the White population, there is evidence of lack of interest in physical science from as far back as the early seventies. A similar picture emerges when the Black population group is considered using more recent statistics.

In Figure 1.1 it can be noted that physical science is the least popular science subject among the Black population groups in South Africa.

> ... the percentages of pupils of the Department of Education and Training [DET] (22,4% in 1980) and the Department of Internal Affairs [Coloured Affairs] (19,7% in 1980) are extremely low and also do not show a rising trend (HSRC 1981: 15).

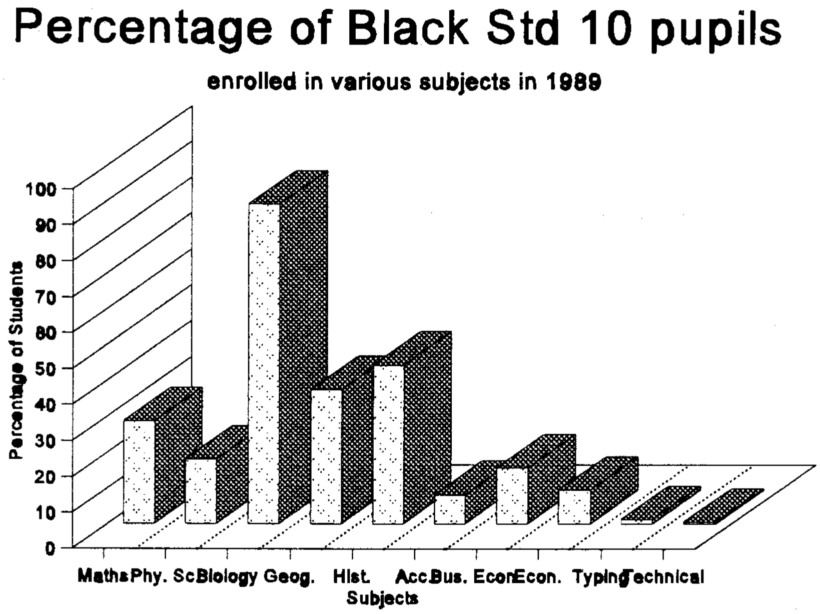


FIGURE 1.1 BLACK STD 10 PUPILS ENROLLED IN VARIOUS SUBJECTS IN 1989 GIVEN AS A PERCENTAGE (Du Plessis, Du Pisani & Plekker 1990: 16).

According to Grayson & Inglis (1990: 6), "Problems experienced by White and Black students are generally not qualitatively different, but are quantitatively different", and "many Black students... frequently lack practical skills, owing to the fact that many Black schools are severely lacking in laboratory equipment."

It is interesting that this dismal situation is not unique to South Africa or only to developing countries; Hewitt has a ready example from a typical first world country:

> For the past several decades, physics has been the least popular science course in U.S. high schools. ...physics courses frustrate average ability students and drive them to despair. ...it has been a course to 'get through' rather than a course to 'get into'... (Hewitt 1990: 55).

The reason for this is that physics courses usually emphasize application that is the final stage of the learning cycle by avoiding the first two stages of exploration and concept development (Hewitt 1990: 55).

Students in Venda offer the Department of Education and Training (DET) Examination. Therefore they face the same problems as students elsewhere in the DET schools in South Africa (Figure 1. 2, Dept. of Education and Culture, Venda, 1990). The problem, as far as the teaching of physical science is concerned, is even more critical in Venda due to certain local factors, some of which will be considered in this investigation.

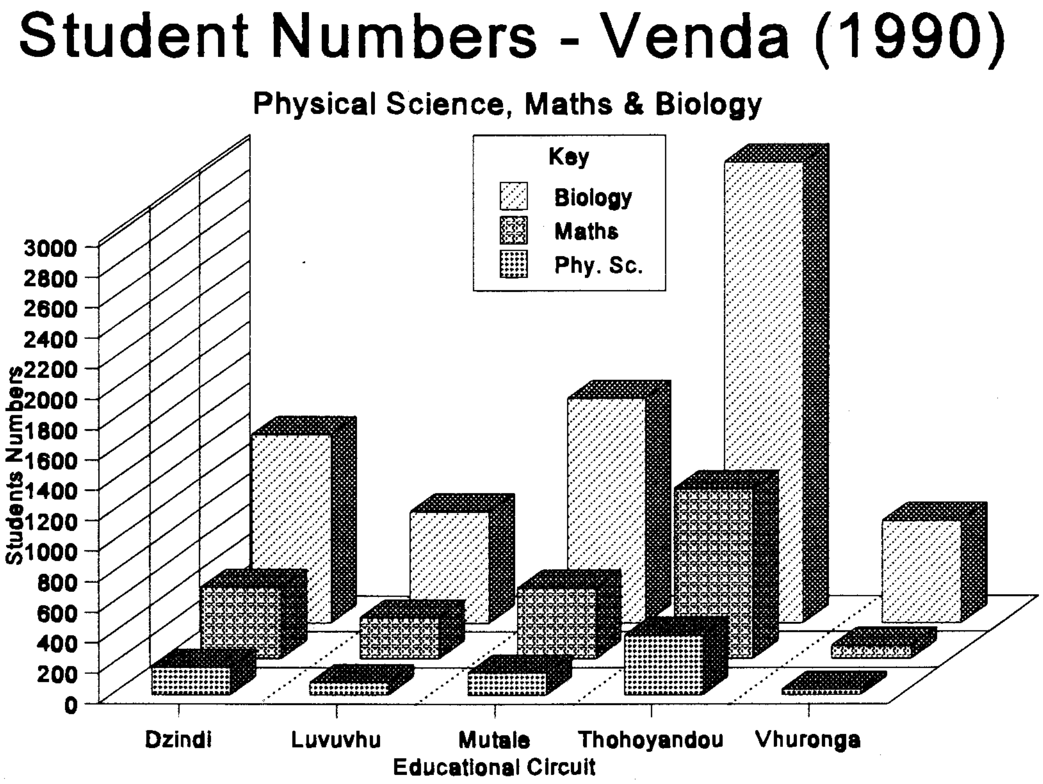


FIGURE 1.2 NUMBER OF STUDENTS ENROLLED IN PHYSICAL SCIENCE, MATHEMATICS AND BIOLOGY IN 5 SAMPLE CIRCUITS IN VENDA (1990) (Dept. of Education and Culture, Venda: interviews and personal communications with officials).

Possible reasons for the declining interest in physical science in White schools in the early seventies, based on extensive research on this topic, are worth recalling here although it is over a decade since this report was first published. In this report, the principals cite

... the length, the degree of difficulty and abstract theoretical nature of the syllabus and the unsatisfactory training and qualifications of physical science teachers as two most important possible reasons for the decreasing percentage of pupils who took physical science (Swanepoel 1982: 188).

In the same investigation, it is reported by 53,1% of the students that "...physical science is uninteresting" (Swanepoel 1982: 195). A more recent study by Grayson & Inglis (1990: 5) gives the following as the reason for the void between high school and the university that influences the Black children:

Authoritarian structure, propaganda, passivity, TV, untrained teachers, violence, detention, poverty, disrupted schooling, unschooled parents, intimidation, textbook shortage, inadequate housing, questionable marking procedures, rote-learning, and overcrowded classrooms.

Of the many factors that could be responsible for this situation regarding physical science education in schools, the researcher would like to consider two that are most relevant to teaching and learning of physical science in schools in Venda:

(a) the lack of physical facilities like equipment and laboratories in many schools in Venda, and

(b) the lack of manpower facilities like experienced and qualified teachers in Venda who are willing to teach this subject with understanding, insight and enthusiasm by breaking away from the traditional authoritarian rote type of teaching.

According to Swanepoel (1982: 54), "...teachers of physical science or general science regard better instruction and presentation as the most important factor that will encourage pupils to take the subject." He further adds that "...principals regard the syllabuses, the qualifications and training of teachers as-well as the instruction and presentation of subject matter as the main factors requiring attention to ensure that more pupils in standards 8, 9 and 10 will take physical science" (Swanepoel 1982: 49). According to this study, much emphasis is placed on better instruction and presentation of the subject matter. It is possible that better instruction and presentation will improve science education in Venda as well. How could this be achieved? There are several accepted ways of improving instruction and presentation of the subject matter in physical science. Some of them are:

1. Using different methods of teaching.
2. Using various teaching aids while teaching.
3. Motivating and involving pupils in the lessons.
4. Making the lesson meaningful to life.
5. Using different resources for information for the lesson besides the textbook.
6. Preparing and planning the lesson thoroughly.
7. Providing training (both pre-service and in-service) to teachers in content and methodology of teaching physical science.
8. Affording opportunities for teachers to upgrade their qualifications.
9. Training teachers to teach physical science using an integrated practical approach to teach science.
10. Encouraging teachers to be innovative and to improvise equipment in order to teach science using a process approach so as to understand science concepts by doing and by that making the subject relevant and meaningful to the students.

How is it possible to bring about these improvements in the schools in Venda? If it is possible to give in-service training (inset) to all teachers as an ongoing process, it could help in the long term. Apparently there are no suitable resources for this to be accomplished or carried out. It will take some time for these needs to be met satisfactorily in this region.

Many schools in Venda have no laboratories or science equipment of any kind. This is more the rule than the exception in Venda. Therefore to provide facilities in schools for science, massive financial investment is essential. School buildings, security, furmiture and equipment have to be provided. Capital outlay for such change will not be possible within a short time in Venda. However, the need for the improvement in science education is real and necessary, and has to be addressed with the least possible delay. This also has to be accomplished without heavy expenditure. There is the need to improve the quality of science teaching with the minimum of funds and infrastructure. Such an action will certainly bring immediate benefit that will result in useful changes in science education in Venda in the future.

1.1.4 TEACHER TRAINING IN VENDA

Teacher training is essential and is taking place both at the colleges and the University of Venda. The Department of Education is ensuring the recruitment of teachers who are qualified to teach by making teacher training a minimum requirement for appointment as teachers. This is a step in the right direction, but it will be a long time before this policy decision has an effect on the quality of teaching in schools. This will depend on the type of training given by the tertiary education institutions concerned. Such training should also go along with the retraining of teachers who are in service so that they are updated continuously as regards teaching content and subject methodology.

Figure 1.3 (Department of Education and Culture, Venda, 1990) gives the teacher qualifications in physical science, mathematics and biology in selected schools in Venda.

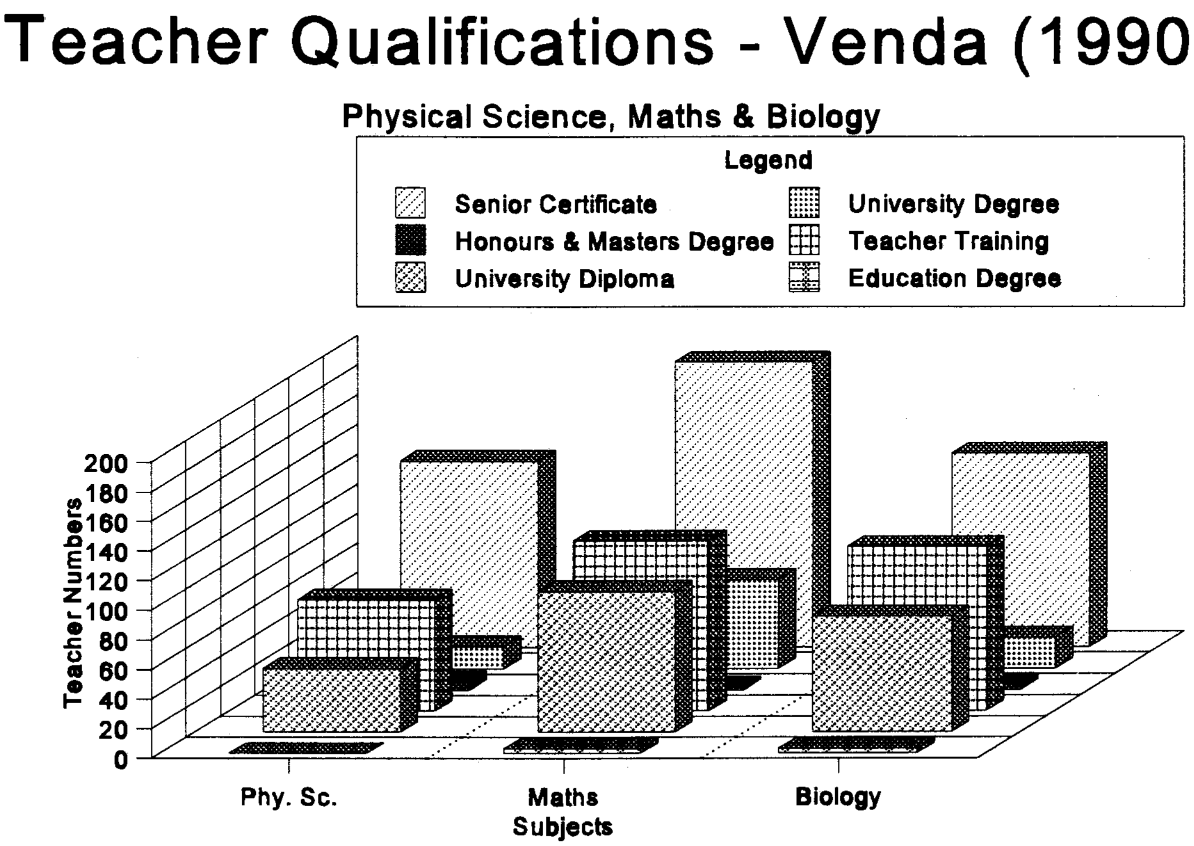


FIGURE 1.3 TEACHER QUALIFICATIONS IN PHYSICAL SCIENCE, MATHEMATICS AND BIOLOGY IN SELECTED SCHOOLS IN VENDA (1990) (Dept. of Education and Culture, Venda: interviews and personal communications with officials).

The striking feature in this figure is that most teachers merely have a Senior School Certificate. A mere 14% of teachers of physical science have university degrees. This figure is lower than those for biology (16%) and mathematics (24,3%).

An examination of the professional qualifications of teachers given in Figure 1.3 shows no physical science teacher in Venda has a degree in education, though this is not so in biology and mathematics. Most teachers teaching physical science in Venda do so with their teacher training alone. Only 36,4% of physical science teachers have a university diploma, whereas 40,6% biology teachers and 44,6% of the mathematics teachers have a university diploma.

It is known that good teachers are usually not retained in their teaching jobs, as they are attracted to more affluent science-based jobs elsewhere. This problem is common, not only in Venda, but also in the rest of the Republic of South Africa as seen as far back as 1981 in the following HSRC recommendations:

> The salary structure and working conditions, particularly of science and mathematics teachers, should be improved with a view to attract more people to the profession and also to retaining those who are already in it (HSRC 1981: 90).

By contrast, it is gratifying to note that "...it can be assumed that nearly 100% of teachers in White schools are professionally qualified, having at least standard ten or higher academic qualifications as well as a teacher's certificate or diploma" (Du Plessis, Du Pisani & Plekker 1990: 18). Yet it is astonishing to find that problems in science education are similar in both the Black and White schools in South Africa. The quality of qualifications of physical science teachers in Venda leaves much to be desired.

According to available figures, many science and mathematics teachers who are in service in Venda have only standard ten qualification and a substantial number of them have no professional qualification of any kind (Figure 1.4, Dept. of Education and Culture, Venda, 1990). This could partly explain why most teachers of physical science rely heavily on the textbooks as their only resource and encourage rote-learning of the content of the subject. This naturally makes physical science an uninteresting subject. Teachers fail to explain concepts in science, as they themselves never got an opportunity to internalise the concepts themselves. Similar thoughts are expressed by Bradley, Brand & Markwell (1989: 21), remarking that "Although the students are graduates, their experiences of both project work and school teaching has usually been very limited." Further, as most teachers have had no training in education, they lack the know-how to initiate useful changes in their teaching. Furthermore, teachers have always been hesitant to change even if it is for the better, and so have been inadvertently responsible for perpetuating the vicious cycle of textbook teaching. This leads to rote-learning without understanding and the mastering of science skills, and makes the subject more difficult and abstract for the students, and thus discourage many students from offering physical science at school.

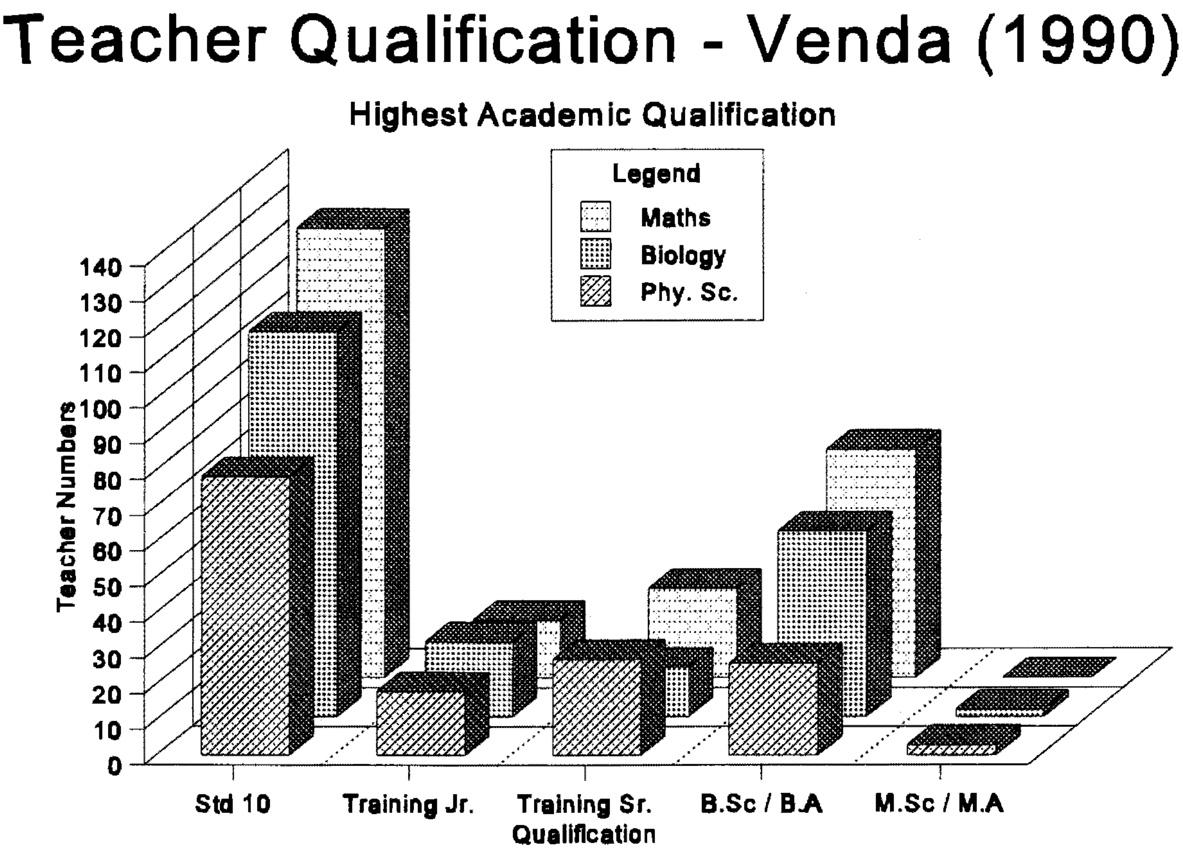


FIGURE 1.4 HIGHEST ACADEMIC QUALIFICATION OF TEACHERS IN SAMPLE SCHOOLS IN VENDA (1990) (Dept. of Education and Culture, Venda: interviews and personal communications with officials).

When teachers explore the solution to a problem raised in class by doing an experiment involving students in class, the teachers will be using a democratic approach in their science classroom.

Suitable conditions for optimum student learning can take place in a democratic classroom where students feel free to clear their doubts by asking questions. In such a classroom the teachers can evaluate their students while teaching. They will know if learning has been taking place with understanding so that the subject is meaningful to the students. The classroom will be a pleasant place for everyone. This is only possible in a relaxed but disciplined didactic situation. It appears that this kind of atmosphere for the proper learning of physical science does not unfortunately prevail in several schools in Venda. Several other factors like student attitude and behaviour, lack of cognitive and metacognitive skills, and the excessive use of punitive measures by the school authorities could hamper proper learning of physical science in schools in Venda. There is much scope for further studies in these areas to improve physical science education in Venda. However, the scope of this study does not allow the researcher to venture into all these varied aspects of investigation that affect science education in schools in Venda.

Teacher-trainees need to be made to re-evaluate several things that they thought were 'normal' in a didactic situation. They must realise that learning by rote is not the best form of learning. They should be prepared to encourage their students to be actively involved in education by arousing their curiosity; they should guide them to be critical, to ask questions and not to be simply passive recipients of knowledge given by their teacher. In science teaching, doing experiments should be considered a way of building a knowledge base rather than a way of verifying certain stated scientific principles. The knowledge base may be built using the inductive and the deductive approaches, which form part of the processes of science (See Chapter 2). These inductive and deductive approaches should be used to supplement each other in the teaching of science. However, it is doubtful if teachers are undergoing such changes within the short period of training at the colleges and the university. The experience of the researcher at the University of

Venda shows that even those who do the postgraduate University Education Diploma (UED) are in great need of training, not only in their methodology of teaching, but also in the approach to the teaching of science which integrates content with practical skills. Their practical knowledge has not been geared to making them better science teachers in schools where science is taught by presenting content and encouraging rote-learning. The graduate teacher-trainees appear not to have internalised the basic concepts of science. They have had their training in the traditional manner, not much different from the way they were taught at school. The approach and methods used for teaching science have to change if science education in schools is to be made attractive and meaningful. There is also a great need for a change in the attitude of the teachers. The following quotation of H. D. Antony regarding modern assessment of Galileo's achievement as given by Chalmers (1980: 1-2) supports the point:

> It was not so much the observations and experiments which Galileo made that caused the break with tradition as his ATTITUDE to them. For him, the facts based on them were treated as facts, and not related to some preconceived idea... The facts of observation might, or might not, fit into an acknowledged scheme of the universe, but the important thing, in Galileo's opinion, was to accept, the facts and to build the theory to fit them.

Any useful change with regards to the approach and method of teaching in the teacher-trainees must be sustained throughout their lives as teachers. Teachers must be made to realise that they are good catalysts of change. They have to aim to work towards change in education that is better for the students.

The teacher training must be so designed as to allow the trainees to experience science, learn it as a process, see and realise the value of doing science and make it useful to real life situations. Ogens (1991: 201) speaks of four ways of justifying the teaching of science: "Science for meeting personal needs, science for resolving societal problems, science for career awareness and science as preparation for further study." Meeting these four needs will be quite demanding, both on the trainee and the trainer. However, the sooner this is accepted as a requirement for teachers of physical science, the better it will be for the future science education in Venda.

This study attempts to focus on two issues that are related to the improvement in the teaching of science in schools in Venda. The first is the provision of opportunities to teacher-trainees at the University of Venda to learn to teach science by doing, using improvised equipment. It is believed that this will result in a better understanding of the subject and how to teach it, help the teachers to be innovative and active and show the usefulness of science beyond the classroom. It will also enable the teachers to do practical work in science in schools that have no laboratories or science equipment. Finally, it will give them the necessary training that will enable them to use science equipment in schools if and when they are available - all in the interest of teaching science by the process and investigative approach - and will lead to child-centred method of teaching science.

The second issue is to provide in-service training to teachers who are already in the school system in the use of improvised equipment in teaching science. This will enable them to perform practicals in their own classrooms even if there are no facilities for doing experiments due to the lack of science equipment in their schools. The in-service training will be conducted as workshops where teachers will have an opportunity to work in groups on apparatuses improvised from simple home-made equipment. Having taken part in such workshops, these teachers get a better understanding of the science concepts they have been teaching their students all along using the 'traditional' methods. Chaudhari's remark seems to be appropriate here:

> ...so far our learning in science has been basically the same as it was a few centuries ago, and we have been learning it in the same way as we have been learning any other subject including classics (Chaudhari 1986: 116).

As a result of these inset workshops, teachers will experience the process approach to science teaching by learning it themselves, and having learnt science by doing, they will be able to use this method in the classroom to teach their students. This will certainly cause a change in their approach to teaching physical science in the classroom, and is bound to improve student learning and interest in the subject. This exposure will help many teachers to realise the value of applications of science in teaching and will encourage them to try other simple experiments in science using improvised apparatus made from equipment at home. As a result, better science learning in the schools will take place in spite of the lack of equipment to do practical work in these schools.

1.2 THE PROBLEM

This study is undertaken to help improve the teaching of physical science in schools in Venda, for the reasons discussed in the previous section. One way of bringing about this improvement is by using the doing method or process approach, that is, by doing experiments in science to understand the subject matter. The process approach to the study of physical science will give the students a hands-on experience of doing science, and thus have ample opportunities to appreciate the value of learning physical science. This will naturally result in meaningful science, learnt at higher cognitive levels that will be useful to the students at any stage in their lives. The teaching of physical science using this method will be accomplished despite such problems as the lack of science laboratories and equipment in schools and the existing poor or unqualified science teachers, who do not attempt to do any practical work in their physical science classes. It is hoped that by giving teachers suitable in-service and pre-service training in the improvisation of science equipment, their understanding of the content and concepts of physical science can be improved. They will in turn be motivated to teach their students physical science by doing experiments using improvised equipment with which they will be now comfortable and quite familiar.

THE PROBLEM STATEMENT

Can improvisation be used as a strategy for the teaching of physical science, so as to encourage better overall learning of the subject and thereby eliminate the ill effects caused by the lack of facilities for doing practical work in the teaching of physical science in the schools in Venda?

1.3 AIM AND OBJECTIVES

1.3.1 AIM OF THE STUDY

The aim of this study is to investigate the effectiveness of using improvisation as a strategy in the training of teachers of science - both at the preset and in-service training (inset) stages - to see if these teachers can grasp basic concepts in science and apply them to their teaching, thereby promoting their pupils' interest in the subject in the absence of science laboratories and equipment in their schools.

1.3.2 THE MAIN OBJECTIVES OF THE STUDY

At the end of this study, it is hoped that answers to the following questions will be found that will help to achieve the aim:

(1) How can teachers be trained to use improvisation as a teaching strategy for teaching physical science in schools?

(2) How will students benefit from improvised apparatuses used by their teachers in the teaching of physical science?

(3) Will the use of experiments with improvised equipment help students involved to make their own decisions?

(4) Will teachers who are given the necessary help be able to improvise apparatus and be in a position to do experiments in the teaching of physical

science in class?

(5) Will the use of improvised apparatus enhance better student understanding of physical science?

(6) Will this method of learning science help students to apply their knowledge to a real life situation?

(7) Will the use of this method in teaching science bestow any other benefits on the student-teacher relation in the science classroom?

Answers to such questions will help in evaluating this approach to teacher training and its effectiveness in improving science education in Venda.

1.4 THE SCOPE OF THE STUDY

The study will be restricted to Venda. Approximately 15 teacher-trainees from the University and 12 teachers, two from each of the six educational regions in Venda, will take part in this project. They will be exposed to different methods of improvisation and they will have opportunities to handle and make their own improvised equipment. There may be occasions when improvisation will not be possible for certain experiments at the matric level as with experiments dealing with electrons or experiments at the micro level. However, the use of this method, wherever possible, will be sufficient to drive home the importance of method along with content in learning science because, as Chaudhari points out,

> ...the only object in teaching a child to count ducks is to teach him to count anything that can be counted. Similarly, our object in teaching science is to develop a disposition in the boys and girls to use the knowledge and method of science in solving the problems faced in life situations (Chaudhari 1986: 119).

Teachers will be given questionnaires at the commencement of the in-service workshop and after they have used the improvised equipment with their students in class. These responses along with the informal discussions with the teachers will be used to evaluate the changes these teachers undergo as a result of using improvisation in their teaching of physical science in class.

Students involved in this project are the senior secondary students from the schools where the participating teachers are teaching. The students are also given questionnaires at the beginning and after they have been exposed to the experiments using improvised apparatus. These student responses are used to analyse the effects of this method of teaching physical science in these schools in Venda.

Similarly with the UED students, questionnaires are given at the beginning and at the end of their course and their responses to the effectiveness of this method in their understanding of physical science are evaluated to find answers to the questions raised previously.

1.5 THE STUDY PROGRAMME

Chapter one formulates the background for the study by highlighting the shortcomings in the teaching and learning of physical science in schools especially in Venda, and examines the various causes for the lack of interest of this subject. The need for the proper approach to the study of physical science is emphasised. Having looked at the present state of science education and the facilities in schools in Venda, the researcher suggests practical steps that could be taken for the immediate improvement of the teaching of this subject. The aim and objectives of the study and the method employed in this research are explained. This section also gives a brief account of the study programme that forms the research outline for this study.

Chapter two deals with the theoretical didactic basis for using improvisation as a strategy for teaching physical science. In clarifying this, an analysis of the nature, structure, epistemology and the teaching of physical science is included. This is done to show the advantages of using this method in teaching science, especially in third world schools like those in Venda.

Chapter three deals with terminologies like "improvisation", "teacher-training", "inset" and "preset". It also discusses the advantages and disadvantages of improvisation as a strategy in science teaching as well as its effectiveness.

Chapter four looks at the effectiveness of student teachers who were involved in making some home-made apparatus during pre-service training in physical science methodology. This will enable them to experience the kind of understanding of physical science that makes their learning process more enjoyable and meaningful. They will realise the effective ways of using simple apparatus for better teaching and learning in class. They will see the several advantages of doing projects using improvised equipment. The benefit of peer teaching using the process approach during preset will be enumerated.

Chapter five examines the research findings regarding the use of improvised apparatus by the selected teachers who are in service in different schools in Venda, where there are no facilities for doing practical work in science. The teachers involved in this in-service training are mostly those who have had no prior science teacher-training and are therefore in dire need of training. The effectiveness of inset workshops in making them better science teachers is evaluated in the light of responses to questionnaires given to these teachers, from the feedback obtained from the performance of the science students from the schools where these teachers are teaching and from informal discussions with the principals, staff and students of these schools.

Chapter six summarises the findings of this research against the background of the problem statement, aim and objectives that were stated in the first chapter. Suitable recommendations for training teachers and for effective teaching of physical science in schools without equipment are made. Steps will also be initiated to remedy shortcomings in connection with the training of science teachers and the teaching and learning of physical science in Venda.

CHAPTER 2

NATURE, STRUCTURE AND EPISTEMOLOGY OF PHYSICAL SCIENCE

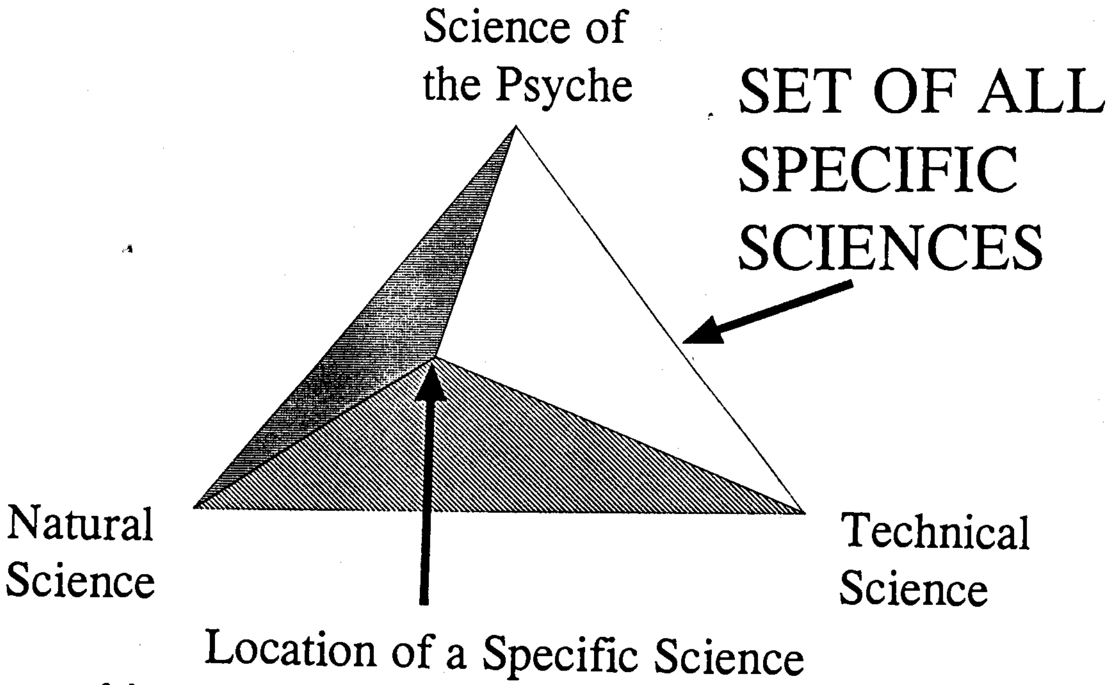
2.1 STRUCTURE OF SCIENCE

Man is a social being. Culture is part of man's heritage that helps him to be sociable in the society in which he lives. Chaudhari (1986: 75) quotes Whitehead (1962) as saying,

> Culture is the activity of thought, and receptiveness to beauty and humane feeling. Scraps of information has nothing to do with it. A merely well-informed man is a most useless bore on God's earth. What we should aim at producing is man who possesses both culture and expert knowledge in some special direction.

Man needs to know and understand his environment. Only then can he live harmoniously in his environment. Today, man has to have a basic understanding of science to live harmoniously with his environment. This is because science, which man has developed over the years, has almost total influence on the earth. Science and technology have been responsible for the vast changes that have taken place in this world that make the life of man comfortable and enjoyable on this planet. As a result, science may be regarded as a part of man's culture, "similar to any other body of knowledge or cultural goods that he may have" (Van Wyk 1993: 4).

The structure of science can be visualised in Figure 2.1 as three fundamental elements that form three poles, namely, human science or science of psyche, natural science and technical science.



The extent of the components contributed by science of the Psyche, Natural Science and Technical Science is represented by the position within the geometry.

FIGURE 2.1 CONCEPTS REGARDING THE STRUCTURE OF SCIENCE (Van Wyk 1993: 5)

> The practice of a specific science is therefore qualified by the tension between the two extremes of specialisation and generalisation: specialisation ensuring greater scientific depth within each specific science; generalisations within the context of science in general also contribute to advancement. Both being essential for excellent science, a sound balance should be struck between these two extremes (Van Wyk 1993: 7).

Another aspect for a proper vision on science is shown in Figure 2.2 (Van Wyk 1993: 6).

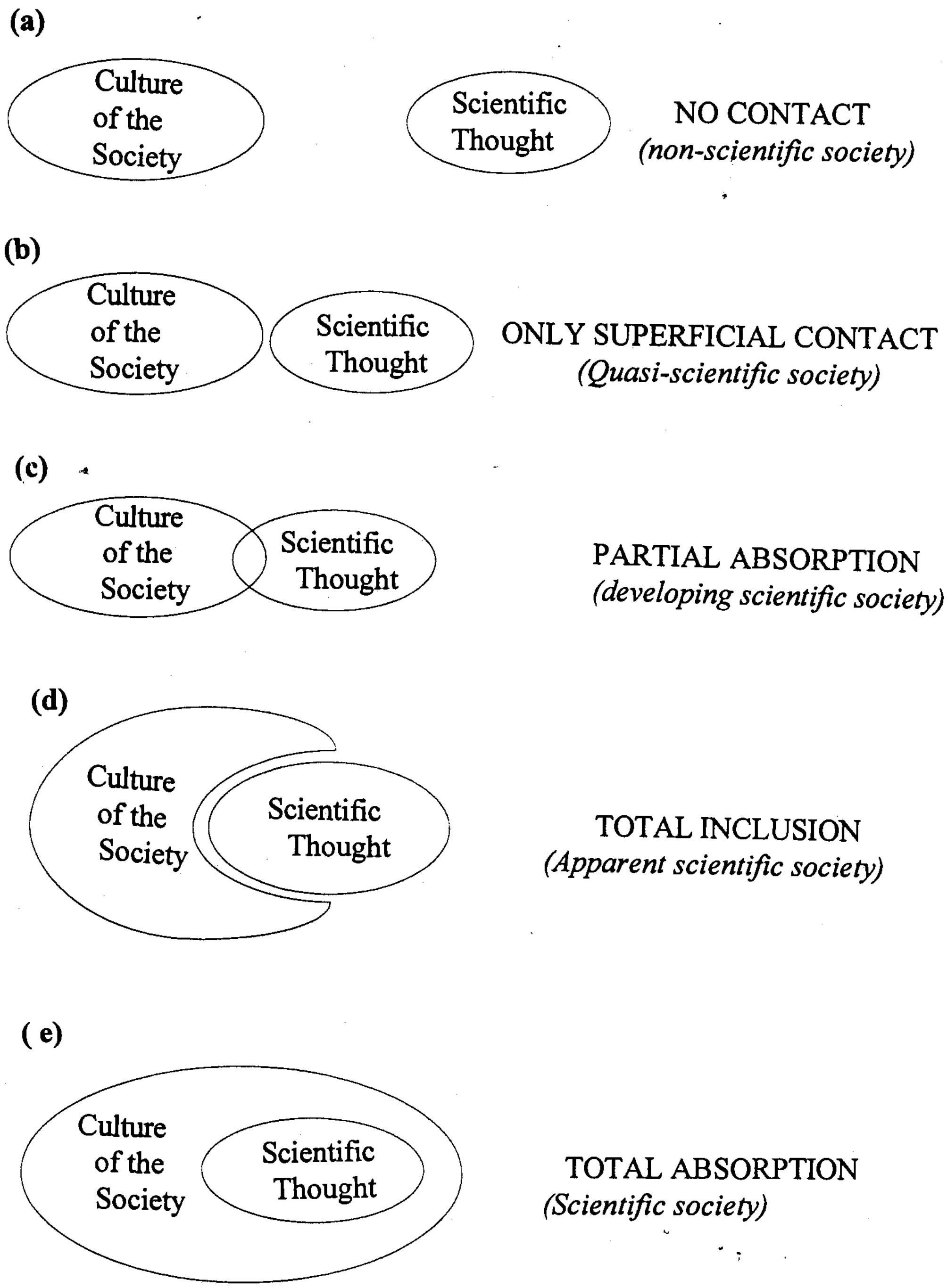


FIGURE 2.2 VARIOUS MODELS OF THE CULTURAL ABSORPTION OF SCIENCE BY A COMMUNITY (Van Wyk 1993: 6)

A community could absorb science into its culture to form an integral part of its culture in five different ways. This is necessary, as we saw before, if science is to be regarded as part of man's culture in this scientific world. The five different stages shown in the figure (a, b, c, d & e) decide the type of influence science could have on any society.

The first stage (a) shows science with no impact at all on the society, as with very primitive societies like that of the Bushmen today. Such societies form the non-scientific society. The second stage (b) represents only casual contact with science. The contact remains superficial and it is inhibited by some cultural, religious and other factors that are opposed to scientific ideas in those societies. This is what Van Wyk calls a quasi-scientific society. The third stage (c) represents the vast majority of societies at the present time - the developing scientific societies. These societies have generally accepted the value of science and science has influenced these societies in many ways. These societies have not yet fully integrated science into their own culture. Such societies will, in course of time, accept more of the scientific values, but whether it will result in total inclusion or total absorption of science into their culture cannot be predicted as it depends on several factors. Again, the prevailing culture of the society will decide if the society will adopt the integration of science fully, or only partially into its culture. Such cultural absorption of science by a community is bound to affect the culture of the society. This influence will eventually result in the development of philosophies of science as part of their culture. Examples of societies in the final two stages, (d) and (e), can be found in European countries. Stage (d) societies are those which have fully included scientific thought into their culture - Wyk's "apparent scientific society." Societies in stage (e) go further: they fully absolve such thought into their culture. Such societies are considered "scientific societies" in Wyk's classification. In Europe, scientific thought has been fully absorbed into the culture of the society and so it is a good example of a truly scientific society as in figure 2.2 (e). As far as this is concerned it is important to remember that when science is absorbed into the culture of a society, there is no need for those societies "like monks, to renounce some very precious aspects of the world" (Chaudhari 1986: 119) because according to science, all human qualities are useful and there is no need for people to change their ways of life or thinking or their traditional culture in a social situation because of the absorption of science into their culture.

Some years ago science did not appear a difficult subject to learn and teach, because science teaching and learning involved the mastery of a set of knowledge. That was in the 1950s, when "physics was concerned with nothing smaller than a brick, when biology was taxonomic and descriptive and when chemistry dealt with preparation and properties (bulk properties only)" (Johnstone 1991: 75). Science was restricted to only a selected few students in some schools. It was not taught to fulfil the need to develop a scientifically literate society. The traditional method of teaching science focused on textbook instruction and teaching mostly at knowledge level. This content-mastery approach to science is organized around discrete topics - planets, electricity, magnetism, mechanics - with little attempts to make connections across topics. The instructional pattern typically consists of reading the text, followed by answering factual questions posed by either the teacher or the textbook. Hands-on activities and teacher demonstrations are added to foster motivation, but are often selected, because they are easy to do for fun, rather than for their usefulness in developing conceptual understanding or higher level thinking. Thus, science teaching (and scientific thinking) is viewed as simple acquisition of facts by students (Ogens 1991: 199).

During the 1960s, in the wake of the sudden awakening in response to the Soviet launching of Sputnik in 1957, science curriculum focused on what scientists knew.

> The 1960s made us stand back and ask serious questions about science, its concepts, its overarching theories and insights, its consequences, its issues and its place in education and in society in general. CHEM Study, P.S.S.C., B.S.C.S. (in all its versions), Nuffield, Scottish Alternative and many, many schemes were launched at that time, all of which tried to address these questions about science. Books such as *Physics for the Enquiring Mind, Physics is Fun, Chemistry takes*

shape, and *Biology by Enquiry* all began to reflect the new thinking about teaching and learning in science". (Johnstone 1991: 75).

According to these views, science educators considered concepts unifying and emancipating - a view that considered large universal patterns, not necessarily the immediate and the perceptual. According to McCormack & Yager (1989: 47), there are five domains of science education. They are:

> Knowing and Understanding, Exploring and Discovering, Imagining and Creating, Feeling and Valuing, and Using and Applying. ...Science education must encompass ALL these domains if it is to help students attain the level of scientific literacy demanded by today's society and tomorrow's needs.

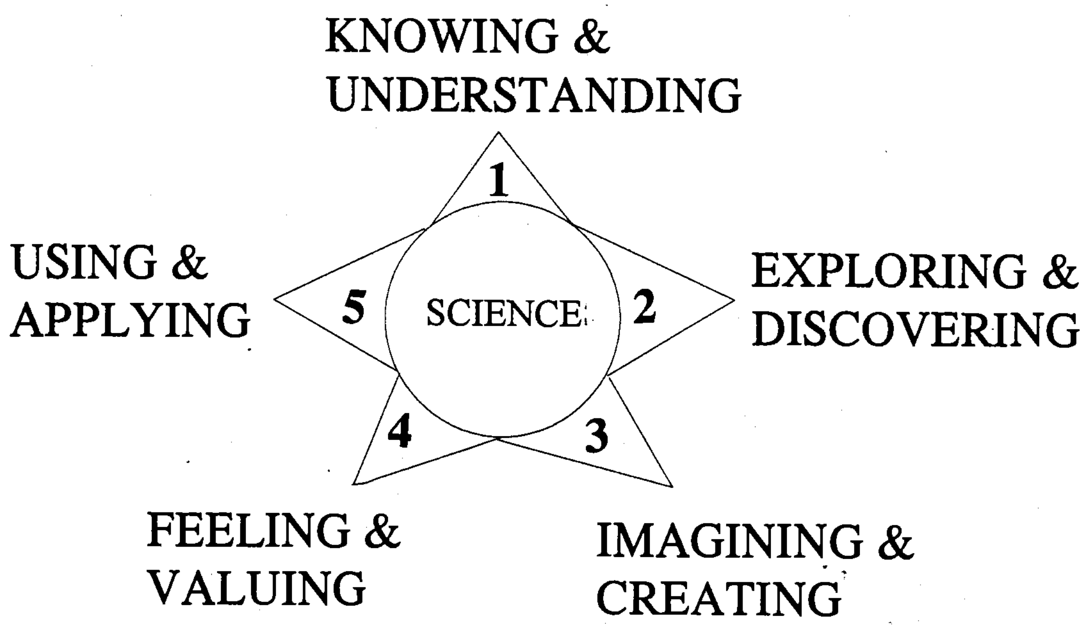


Figure 2.3 THE FIVE DOMAINS OF SCIENCE EDUCATION (McCormack & Yager 1989: 47)

Figure 2.3 (McCormack &Yager 1989: 47) illustrates the five domains. In this classification, the knowledge and understanding domain is the only one concerned with scientific knowledge. All the other domains include some aspects of scientific processes, methods and/or attitudes besides scientific knowledge.

> The main drawback of science teaching in our country is that instead of striking a balance between the 'content' and 'method' or 'product' and 'process' we have been emphasizing all through these years only the 'knowledge' or 'product' aspect of science. The 'process' approach has been relegated to background. This has led our children and youth to blind learning of scientific facts and figures without understanding their significance or use. They have become simply 'consumers of scientific achievements, never interpreters or appliers or producers of new ideas'. A lack of scientific outlook is discernible even in the Masters and Doctors of Science (Chaudhari 1986: 116-117).

Chaudhari's remark applicable to India is also applicable to Venda as seen from the report of the Commission of Inquiry into the System of Education in Operation in the Republic of Venda which speaks of the lack of laboratories in secondary schools and mentions that of the 107 schools, according to 1981 figures, only 17 have laboratory facilities and of them only 11 have basic equipments (Report of the Commission of Inquiry into the System of Education in Operation in the Republic of Venda, 1982: 58). From the observations and enquiries made by the researcher, this situation appears to have only deteriorated over the years. The report further mentions that the curriculum structure in Venda in 1982 as showing evidences for

> ...a powerful subserevience to the demands of an artificial examination system which in turn has restricted the growth of any real structure for curriculum renewal and development ...encourages passive, reception and rote-learning rather than active, skills oriented learning. The products of learning are overemphasised at the cost of the processes required in meaningful learning (Report of the Commission of Inquiry into the System of Education in Operation in the Republic of Venda 1982: 66).

According to the classification proposed by McCormack & Yager,

> There is no evidence that mastery of the domains of knowledge or process, is a prerequisite for learning and experience in the other domains - or that those two domains are more valuable than the rest... By letting students view science from only one or two domains, we may be depriving them of the opportunity to see the richness of science (McCormack & Yager 1989: 48).

2.2 EPISTEMOLOGY OF PHYSICAL SCIENCE

Physical Science is "any of the sciences, such as physics, chemistry, astronomy and geology that analyses the nature and properties of energy and nonliving matter" (Reader's Digest Great Illustrated Dictionary 1984: 1284). Physics is the study of the natural or material world and phenomena and is also considered natural science or natural philosophy according to a broad meaning given in the same dictionary. However, in the definition of recent scholars, it is

> the science of matter and energy and of interactions between the two. It is based on mathematics and grouped in traditional fields such as acoustics, optics, mechanics, thermodynamics, and electromagnetism. In modern physics, relativity and quantum theory are used and other areas of study include atomic and nuclear physics, cryogenics, solid state physics, particle physics, and astrophysics" (Reader's Digest Great Illustrated Dictionary 1984: 1284).

The following are a few definitions currently in use, both in dictionaries and textbooks, as given by Maarschalk & McFarlane (1988: 42):

> Physics (is) the science of matter and energy (Lindsay 1971: 13).
>
> Physics is the science of matter and is concerned with its fundamental structures, properties and behaviour (Beiser 1978:(i)).
>
> Physics is a science that has as its objective the study of the components of matter

> and their mutual interactions. In terms of these interactions the scientist explains the properties of matter in bulk, as well as the other natural phenomena we observe (Alonso & Finn 1971: 2).

> ... physics can be defined as a science which investigates that aspect of reality as is found in non-living objects in the cosmos. ... physics is directed at a study of God's Creation insofar as creation can be studied by means of observation (Maarschalk & McFarlane 1988: 43).

Chemistry on the other hand is "the science of the composition, structure, properties, and reactions of matter, especially of atomic and molecular systems" (Reader's Digest Great Illustrated Dictionary 1984: 307).

> Chemistry has been described as the science that deals with matter and its transformations, in contrast to physics that is concerned largely with energy and its transformations. Physical chemistry may be regarded as an intermediate field involving the study of the interactions between matter and energy. Inorganic chemistry deals primarily with the actual nature of the material changes occurring in chemical reactions (Gladstone & Lewis 1961: 1 as reported by Maarschalk & McFarlane 1988: 43).

Physics can be considered the science of matter and related aspects such as energy, work and power, while chemistry can be considered as dealing with types of matter and the changes matter undergoes from one form into another.

Astronomy is "the scientific study of the universe beyond the earth, especially the observation, calculation, and theoretical interpretation of the positions, dimensions, distribution, motion, composition, and evolution of celestial bodies and phenomena" (Reader's Digest Great Illustrated Dictionary 1984: 113).

Geology is "the scientific study of the origin, history, structure, and processes of the earth" (Reader's Digest Great Illustrated Dictionary 1984: 700).

Physical Science is different from Life Science that deals with the structure and function of organisms. Life Science may comprise subjects like botany, zoology, biochemistry, genetics, or immunology. Physical science and life science together form what is generally called the general science. In recent years, general science has come to be considered as an integrated science to show that different sciences are interrelated to one another. A reason for introducing the idea of integrated science in schools at the secondary level is to make science more meaningful to the students. The thematic approach to the study of science is also aimed at giving a global view and understanding of science that is essential to form the broad base understanding of science to be properly integrated into the culture of the society. The artificial compartmentalisation of science into physics, chemistry, botany, zoology and so on, is for the convenience of people. However, when studying any subject, the other sciences are involved in varying degrees and they do influence each other. For students to have a global view of science, it is better to deal with the specialised branches of science as one integrated science, rather than the compartmentalised packages of different sciences. This is essential as the main concern today is to provide "science for all" and "science for life" so that science learnt at school will be used in the life of the students, whether these students are immediately employed or they go on to further their education.

As indicated above, physical science is composed of physics, chemistry, astronomy and geology that are all concerned with energy and non-living matter. However, when we speak of physical science today, we normally consider it to be composed of only physics and chemistry. The other two components, namely astronomy and geology, are normally not taught in any great depth today in schools in their physical science curriculum.

Science education in South Africa has come under the spotlight in the last decade, and there is growing anxiety about the inability of science education to meet the needs of the New South Africa. The general feeling is that something is wrong, and no one knows what that is or how to put that right (Levy 1992: 45). There are several related factors contributing to this dismal situation of science education in South Africa today. It is worth looking at these to explore ways of overcoming the problems facing science education in South Africa. Levy views the situation as follows:

> ...most of the science taught in schools has to do with measuring and observation. We see here an emphasis on technique rather than PROCESS. What about seeking explanations for natural phenomena? What about testing hypotheses? What about the innumerable aspects of being a scientist? ...The point I am trying to make here is that the image of science we are presenting is largely empiricist. Science is seen to consist of facts and formulae that describe the world as it is (Levy 1992: 45).

Levy goes on to share with us her view of what science is and does:

> Experience tells us that science is not absolute, immutable, infallible knowledge, untainted by human subjective experience...yet we teach science as a fixed closed body of knowledge. We teach that science is about facts, and that facts are authoritative. History and process are excised. What we forget is the critical role humans have played in deciding what we now come to accept as 'facts' (Levy 1992: 45).

We should also remember that the facts we now accept today as science will change in course of time as more scientific knowledge is discovered because "the growth of science is continuous, ever onward and upward, as the funds of observational data are increased" (Chalmers 1980: 5). This dynamic nature of science is brought out as a metaphor by Popper quoted by Chalmers (1980: 63):

> The empirical basis of objective science has thus nothing 'absolute' about it. Science does not rest upon solid bedrock. The bold structures of its theories rise, as it were, above a swamp. It is like a building erected on piles. the piles are driven down from above into the swamp, but not down to any natural or 'given'

base; and if we stop driving the piles deeper, it is not because we have reached firm grounds. We simply stop when we are satisfied that the piles are firm enough to carry the structure, at least for the time being.

Newton expressed a similar idea when he said, "If I have seen a little further, it is by standing on the shoulders of Giants" (UNESCO 1983: 21).

Considering the socio-political factor that has an impact on science education in this country,

> ... the mystification of science and the notion of 'expert' are particularly prevalent in South African Society ...the idea that knowledge is transmitted from the expert to the one who is ignorant is commonplace, South Africa has a particularly exaggerated form of the same authoritarian view of science. ...The explanation for this is rooted in the deeply authoritarian society we have grown up in, a society supported by an education system founded on the bedrock of fundamental pedagogics which is inherently authoritarian and narrow...(Levy 1992: 45-46).

Learning a subject such as physics or chemistry is often thought to consist of the transfer of a body of knowledge to the student. The interaction of the learner's existing knowledge, beliefs and skills with the ideas presented by the teacher is supposed to produce a synthesis of the old and the new which leaves neither unchanged (Hewson 1980: 397). The unsatisfactory interaction between existing and new knowledge causes the difficulty in learning a new scientific subject. The learner should function more as an active participant in the construction of his or her own personalized knowledge than as a passive recipient of collected wisdom. This active constructivist view of learning is supported by a rapidly-growing body of research that seeks to analyse the conditions that are necessary in a discipline such as physics or chemistry (Hewson 1980: 397). Two assumptions form the basis of this view. One is that the knowledge which people already possess is important in their attempt to make sense of their experience. This belief is expressed succinctly by

Ausubel (in Hewson 1980: 397) as follows:

> The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.

The second assumption about human thought and behaviour is that people strive to make sense of the natural world (Hewson 1980: 397).

In a quasi-scientific society and, to a lesser extent, in a developing society as shown in Figure 2.2 (b) & (c), existing knowledge in a society may contradict the scientific knowledge and could cause conflict not only to the students but also to the teacher of science who has his own culture. There is also the problem of the culture of authoritarian society that dictates that teachers are the final authority in their subjects. These socio-cultural factors influence the learning and the teaching of science. Under such conditions, teachers need not make any effort to find out what the students know prior to the lesson, because the teachers know that the students will accept what they say without any question. In such situations "...knowledge is treated as something outside rather than inside the minds or brains of individuals" (Chalmers 1980: 115).

Existing knowledge is supposed to be in the form of large units that help to link with one another and with the new knowledge to form a complete whole. The idea of 'knowledge unit' is given different terms under different conditions (For example *script, frame, schema, large-scale functional unit* and *conception*) (Hewson 1980: 398). Hewson uses the word 'conception' as a general term to describe this organized knowledge. He is of the opinion that the appropriate context of a question is important to help the student to recollect appropriate features of a question.

Different people see the same event differently. This is what phenomenology advocates under speculative philosophy. Teachers should be aware of this for effective teaching. Hewson (1980: 398) applies this to conception and says,

> Even when different people can solve the same problem satisfactorily, they can have different conceptions. These differences are particularly striking between groups of beginners (first year physics students, all doing very well at physics) and experts (physics graduate students).

Perhaps that is what Hanson (in Chalmers 1980: 24) meant when he said, "There is more to seeing than meets the eyeball." The visual experience of an observer or what one sees on viewing an object depends on many factors like his past experience, his knowledge and his expectations (in Chalmers 1980: 25). This is a necessary consideration in the learning of physical science that depends much on observation. Naive inductivists assume two things of which the first one is that "science starts with observation" and the second one is that "observation yields a secure basis from which knowledge can be derived" (Chalmers 1980: 22). However, by induction and observation, several different statements could be made, but these different observed statements are only meaningful in science, if a universal statement should be constructed from them by induction. Precise, clearly-formulated theories are a prerequisite for precise observation statements. In this sense theories precede observation (Chalmers 1980: 28-29). But "observation statements are as fallible as the theories they presuppose and therefore do not constitute a completely secure basis on which to build scientific laws and theories" (Chalmers 1980: 30).

Chalmers' inductivist idea (Figure 2.4 (Chalmers 1980: 6)) is expressed in a schematic form (below):

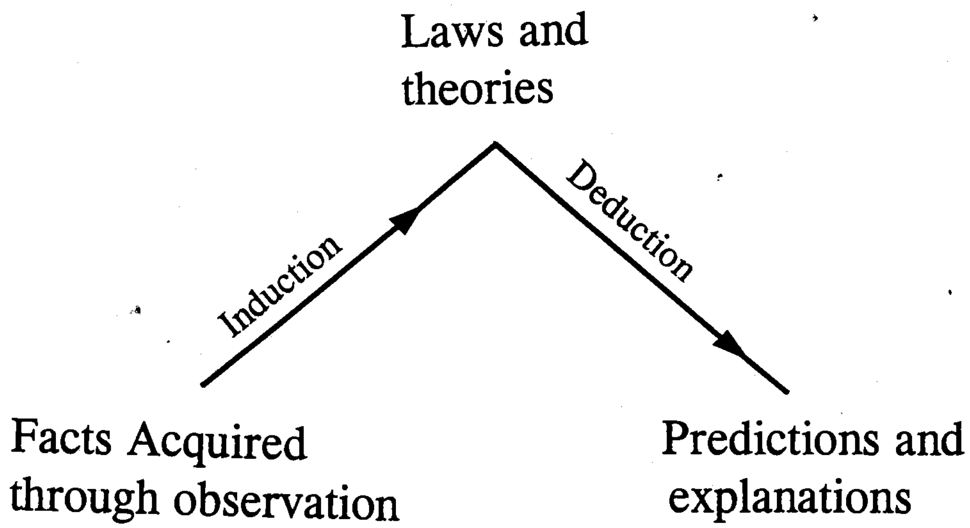


FIGURE 2.4 INDUCTION AND DEDUCTION IN SCIENCE (Chalmers 1980: 6)

The left-hand side of the figure refers to the derivation of scientific laws and theories from observation that has already been discussed. The right-hand side of the figure is concerned with logic and deductive reasoning. They are both useful in scientific thinking. Chalmers (1980: 5) has the following to say concerning the use of deductive reasoning in science:

> Once a scientist has universal laws and theories at his disposal, it is possible for him to derive from them various consequences that serve as explanations and predictions. For instance, given the fact that metals expand when heated, it is possible to derive the fact that continuous railway tracks not interrupted by small gaps will become distorted in the hot sun. The kind of reasoning involved in derivations of this kind is called DEDUCTIVE reasoning. Deduction is distinct from the induction... (Chalmers 1980: 5).

Deduction and induction are thought to be useful in science, because through observation, singular or observation statements are made, which form the basis for formulating universal statements. Singular statements cannot be used for generalisations. Such observation statements could be made on observation by perceptual experience of an observer. Based on several such observation statements, universal statements could be derived. Such universal statements form the laws and hypotheses in science. But for universal statements to be derived from such sets of observation statements, a theory of some kind must precede all observation statements. Therefore observation statements could be as fallible as the theory they presuppose. This argument points out the folly of the inductivists, that science starts with observation. It also brings out the fact that scientific knowledge is composed of incomplete theories that could change and the way forward in science is by improving and extending our theories and not by recording an endless list of aimless observations.

2.3 METHODS OF TEACHING PHYSICAL SCIENCE

Successful student learning could have taken place only if there had been proper instruction by teachers in a didactic situation. The question here is, how best could teachers ensure effective instruction and successful student learning? There are several accepted didactic principles that may be applied in a teaching-learning situation to promote proper student learning. These are useful in the teaching and learning of any subject. It must be remembered that effective teachers always use several different methods in their teaching. However, there are some methods that are particularly useful in teaching science subjects. In this section, some of the methods that are useful in teaching physical science are discussed so that teachers may use them for effective teaching in schools in Venda. It is hoped that will help to make science more popular among students and will also help in removing the misconception that physical science is a difficult subject to study.

Teaching methods are as varied as there are teachers. Though there are several accepted principles and methods of teaching, there is no single method for teaching a particular subject at a particular level in a particular place. "There is as yet no comprehensive theory of teaching and no generally accepted criteria for evaluating teacher-effectiveness" (Chaudhari 1986: 130-131). Teaching, adds Chaudhari, is not a 'mirror image' of learning (Chaudhari 1986: 131). Teachers show their innovative abilities and use their own individuality in teaching. In so doing, some attain greater success than others. This is because there are various ways of successful teaching; there is no magic formula for success in teaching. For teachers to be continually successful in their teaching career, they should be aware of the various principles of teaching so that they know the various alternatives available for them to do their jobs effectively. It is only then that they will be able to use their discretion in making their lessons successful. Consequently, three different principles of teaching that are suitable for teaching physical science will be considered: (a) motivation, (b) activity, and (c) perception.

2.3.1 PRINCIPLE OF MOTIVATION

Teaching is a human activity that involves two or more people. There must be one who is willing to teach and at least another who is willing to learn. Usually in a classroom situation, there is the teacher or educator teaching a group of students. A teacher, by the acceptance of his profession, becomes a willing partner in this didactic situation, responsible for educating the students. Simply taking on the responsibility for teaching does not by itself make him a good teacher. For education to take place, the other partner involved in the process, namely the student or educand also has to be actively involved and be a willing party: he must be willing and prepared to learn from the teacher. This is why he is called the learner. Students who attend an educational institution subject themselves to be taught. This cannot be taken to mean that they are actually willing to be educated. They could be at school because of several other reasons, for example, because their parents want them to attend school. Unless students who are young and generally not responsible enough at this age are prepared and motivated to learn, no useful learning can take place. Willingness to attend school must not be borne out of compulsion or from outside pressure, such as the fear of punishment for not studying; it must come from within for the learner to benefit. If not, as with the proverbial horse, one can force it to water, but can never make it drink: one can teach a student but cannot make him learn anything. Teachers should be aware of this basic principle of motivation, and use methods suitable to motivate their students to learn willingly. Such student willingness to learn, arising out of the free will of the student, is what Duminy and Söhnge (1980: 33) call positive, internal or intrinsic motivation. When students are motivated to learn, they are normally alert and receptive to the teacher and his lesson.

Learning is a mental process that involves thinking, and for a student to use his thinking ability, he must be relaxed. No learning can take place in a panic or stressful situation. This is one reason for advocating that the classrooms be made pleasant places for students to study. Not only the classroom, but the whole school should be an attractive place for students to go. It should not be a place where students are threatened, intimidated or punished. It should be a place where students can socialize and interact with one another and enjoy learning together. In school, there must not only be learning, but also growth - growth of the mental faculties as well as growth of the physical faculties - of the child. This is why schools cater for many extracurricular or non-academic activities so that the aesthetic, moral, religious and physical needs of the growing children are satisfied. Facilities for sports and hobbies ensure the total development and socialization of the children. These help them to get the training necessary to fit them in the larger community into which they were born, and become useful citizens of the world.

Considering the schools in Venda and other homelands, it is worth asking if they are indeed pleasant places for students to go. Do most of the students look forward to going to school or are they normally terrified to go to school? Do they attend schools out of their own free will or are they there because they are forced to be there?

From the researcher's observations and discussions with members of staff and students, it appears schools in the former homelands, including Venda, are far from the pleasant places students can find to study. There are several reasons for this. The classrooms are overcrowded. Teaching aids are few. School environment is not appealing to young minds. There are poor libraries, if any, in these schools. Facilities for sports and entertainment are lacking. Above all, teachers and principals in these schools continue to use corporal punishment excessively. They have been using their 'traditional authoritarian methods' of teaching for a long time. Parents and teachers alike firmly believe in the saying 'Spare the rod and spoil the child.' This is why during this study some teachers and principals went to the extent of claiming that education would take place only when students were subjected to corporal punishment. In fact some openly declared that 'the only language students understand is punishment.' Students and teachers are not considered to be partners in the process of education. It was always believed that students must play a subservient role and teachers a superior 'know-everything' role. This situation in the homelands and 'independent countries' in South Africa changed in 1990 with the release of Mr Nelson Mandela from prison and other radical changes that accompanied this event. Some of these changes took the form of mass student uprising in Black schools in these areas. As a result, students almost took control of the running of the schools. They formed a strong student body - the Student Representative Council - and eliminated the class monitor and the prefect system in schools that they associated with the apartheid era. Because of their sheer physical strength of numbers, students were in a position to dictate terms to their principals, teachers and other authorities. They called for the total abolition of corporal punishment in many schools in those 'countries'. Thus, students were recently responsible in bringing about radical social and cultural changes - for better or worse - in education in South Africa.

Learning took place in these schools traditionally because of the negative or external or extrinsic motivation (Duminy & Söhnge 1980: 33). This was a very important motivation for the student - not only for learning to take place - but to satisfy a most fundamental human need of safety requirement by avoiding punishment. According to Maslow's hierarchy of human needs theory on human motivation(quoted in Biehler & Snowman 1982: 375) people have two basic needs that should be met: deficiency needs and growth needs. According to Maslow, deficiency needs should be satisfied starting from the most basic at the bottom, before any of the other needs above it can be fulfilled. Physiological needs and safety needs are right at the bottom of the deficiency needs in the hierarchy. Only when these are met satisfactorily can a student be expected to go on to fulfil his other higher needs like love, esteem and education that come under the growth needs that are right at the top of the hierarchy of needs. A student who is hungry or whose safety is in danger cannot be expected to appreciate art, music, and other finer things in life to study to know and understand any subject. In the traditional teaching method, punishment in class is expected to make the students study. They study to meet their basic safety needs - to avoid being hurt and being punished. Here, the motivation for learning is negative. Therefore, learning, which is usually a productive and an enjoyable activity, assumes a negative meaning to such students. Learning must result in some useful change in a person. It must take place with satisfaction and understanding, and for this to happen, it should be from within a person. A student should want to learn to satisfy his growth needs, as Maslow suggests in his hierarchy of needs (Figure 2.5, Biehler & Snowman 1982: 375).

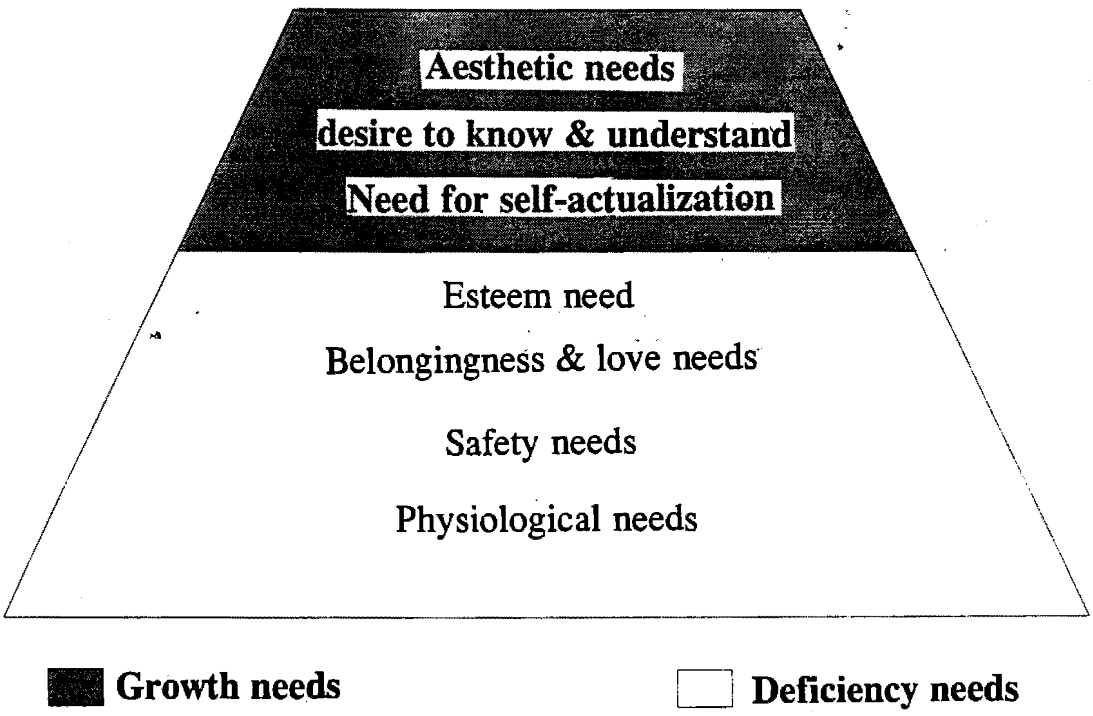


FIGURE 2.5 MASLOW'S HIERARCHY OF NEEDS (Biehler & Snowman 1982: 375)

There must be willingness on the part of the learner, so that what he learns will serve its purpose. For this to happen, students should have intrinsic motivation to learn. Their learning should not be because they simply want to avoid punishment. This desire to learn from within should also be sustained throughout their learning period. The desire coming from within the learner also has to be reinforced and revived from time to time by the teacher during his teaching. The teacher, in the mean time, still remains an authority in this didactic situation. Learning should take place as a two-way process - interaction between both the students and the teacher. These two parties should play active roles in this process; therefore, both are bound to undergo changes for their own good. This would be the most conducive kind of educational situation.

How can a teacher cause and sustain intrinsic motivation of student learning? One way is to make the subject interesting to the students. It should have relevance to them. It must have meaning and the student should see its connections with other subjects and with life. Teaching must be a stimulating and challenging activity to both the teacher and the student. It should not be a process in which the teacher assumes a know-all role, and his authority students must always accept without question. Teachers must show great enthusiasm in their lesson. A lesson must start from known facts and gradually the unknown and the difficult parts will unfold. The content should be developed gradually and systematically from simple to complex, and from concrete to abstract. Teaching should take place in a way that the teacher uses the natural curiosity and the interests of his students to generate interest and thus motivate them to want to know more of what is being taught in a lesson. Jansen (1991: 22-23) gives a few hints for teachers to improve their teaching methods. Some of them, in no particular order, are:

* Don't lecture your pupils. Don't tell them everything -let them discover things for themselves.
* Be dramatic! Be a real actor! Always perform experiments like a professional showman.
* Learn to ask questions properly. ...Arrange all your questions in a logical manner so that each question quite naturally leads to the next one.
* Ask a question, give enough time for reflection and then ask one pupil to answer. Always encourage the pupil no matter how wrong his answer may have been.
* Use the natural curiosity of children. Remember nothing drives a person more crazy than if you know a secret and he doesn't.
* The start of a lesson is very important. If possible, the introduction should start with a "discrepant event" - some strange dramatic action that will immediately capture the audience for you.
* Evaluate yourself at the end of each lesson. Remember the adage: "the best

time to prepare a lesson is after the lesson"? This is the ironic truth about teaching - we do know afterwards how we should have taught the lesson.

* Never drill your pupils like parrots.
* Enjoy your job as a science teacher! There is so much fun around, but you need to create it. Be imaginative, resourceful and creative. Start today, by talking less, doing more and involving the pupils all the way.

Asking the right kind of question is helpful in teaching: it involves the students in the didactic situation. There are three phases of questioning to help in higher level thinking. "Phase One would concentrate on encouraging teachers to ask questions demanding not mere recall, but interpretation and translation. Phase Two would emphasize questions requiring convergent thinking (application and analysis), while Phase Three would emphasize those calling for divergent thinking (synthesis and evaluation)" (Chaudhari 1986: 4-5). The teacher has to be alert all the time and be ready to tap the interests of his students to keep the desire to learn bright and burning in his class. Though students have individual differences, all young students show similar interests. For intrinsic motivation to take place, the classroom must be made an attractive place so that students will want to go there. It should not be a threatening place, as it is today in many schools. In other words, for proper learning to take place, the students must be relaxed and wanting to learn, and must feel free to ask questions that will satisfy their curiosity and will help in sustaining their desire to learn and know more of what is being taught. For this to happen, the teacher has to come down from his position of authority to the level of the students and ask thought-provoking questions so that students are made to think for themselves and formulate solutions while learning. Once they are trained to think and ask questions of their own about the things they learn, they are involved in the lesson, and interest naturally arises. This also gives them a sense of involvement. As the great philosopher Rousseau said in 'Emile', "... it is not a question of teaching him the sciences, but of giving him a taste for them, and the methods of acquiring them when this taste is better developed. This is most certainly a fundamental principle in all good education" (Cahn 1970: 165).

Are teachers striving to develop this enthusiasm and interest in students so that they are motivated to learn more? If they are, then nothing can stop the students from going ahead with their education, if necessary even on their own initiative. Even if there are no teachers to teach them, they become active and show initiative and creativity to go on with their education.

2.3.2 PRINCIPLE OF ACTIVITY

Motivation can lead to active involvement in education. Active involvement is necessary for education to take place. The teacher acts as a guide, giving the correct direction, and the students are actively involved in the learning process. For a student to be actively involved in the learning process, it is necessary for him to realise the usefulness of what he is learning. Usefulness of a lesson to life situations must be highlighted by a teacher as he goes on with his lesson. This may be the direct usefulness we find in our day-to-day lives, or the usefulness we indirectly find at a later stage in our lives. To accomplish this, a teacher should be versatile and be able to play several roles while teaching science.

He should engage in several activities with his students to bring about meaning to the subject. Activity in science should involve both the mind and the body. We have observed that mental activity can take place through motivation and a desirable classroom atmosphere. In such circumstances, the students are involved in the didactic process out of their own free will. The aim of any teacher should be to bring out the hidden talents of his pupils. It is necessary for teachers, as Socrates did with the slave boy Meno, to bring out the hidden knowledge in students from within by suitable means. To do this, they should be aware that children possess knowledge and that they are not born with an empty mind. Students should not be viewed as empty vessels waiting to be filled with knowledge. They are not mere blank paper or 'Tabula Rasa' (blank slate), as John Locke called it. This idea that students too possess knowledge of their own is new to the culture of teacher dominance, and it will be rather difficult for teachers who are rooted in the tradition of authority to accept this view and change accordingly. A little imagination will tell us that there are indeed many students who know several things (depending on their interests), which a science teacher may not know. If a teacher accepts this situation and uses democratic participation of students in his lesson, then teaching and learning become an enjoyable process. It will mutually benefit both the educator and the educand. As a result, much learning will take place during their interaction. Under such circumstances, a teacher of science should guide his students in doing activities that will help them in learning and bringing out their hidden talents. As science is a practical subject that involves doing experiments, it is a good training for students to do their own projects and investigations that give them the necessary 'feel' of doing science. When students are involved in activities on their own, in and out of class, they develop their hidden talents, learn to interact and communicate with one another, and with others; they seek help from outside sources, become independent and develop self confidence in what they do. Doing experiment is very important in science. As Wellington observes, "Doing science is a 'craft activity', depending on personal knowledge and affective attributes such as motivation and confidence" (Wellington 1989: 3). Unfortunately, there is evidence that not much activity goes on in science teaching in Black schools. In the exhaustive report on Investigations into Education in Teaching of Natural Sciences and Mathematics, conducted by the Human Sciences Research Council as early as 1981, it was reported as follows:

> There is consensus that in the main, laboratory work is inadequate especially in Black, Indian and Coloured schools. The reasons advanced for this are:
>
> (i) no laboratories in schools;
>
> (ii) inadequately equipped laboratories;
>
> (iii) high student: staff ratio making meaningful, individual laboratory work very difficult;
>
> (iv) teachers' lack of experience in using the equipment;
>
> (v) pressures of long syllabuses, lack of technical assistance and the time required for laboratory preparation for experiments, making

it very difficult for teachers to cope with practical work;

(vi) absence of suitable laboratory manuals (De Lange 1981: 32).

All the above findings are fully applicable to the situation in most schools in Venda. There are no laboratories in most schools and in those where there are, facilities to use them are lacking to a great extent. The lack of training to use the available equipment and the teacher's lack of experience in handling science equipment and apparatus in front of some class form great drawbacks for teachers. Dreckmeyr makes the point by quoting the famous old Chinese proverb, which is strikingly appropriate to the importance of doing science rather than learning science:

'I hear and I forget;
I see and I remember;
I do and I understand.' (Dreckmeyr, 1988: 27).

2.3.3 PRINCIPLE OF PERCEPTION

Simple knowledge of subject matter is generally not adequate for motivating pupils to be actively involved in a lesson. That does not mean knowledge of the subject matter is not important. Obviously knowledge is necessary for the proper teaching and learning of any subject. In education, one should know the facts, but education must lead one to learn beyond the knowledge level. Learning should lead to the understanding of the content, the ability for a student to be in a position to apply his learnt and understood knowledge to any situation and analyse the subject matter so as to synthesise it and make his own judgement at the end. He is then in a suitable position to make his own judgement during evaluation. These are the findings of Benjamin Bloom, according to the Taxonomy of Educational Objectives, Cognitive Domain in his famous work entitled "Handbook on Formative and Summative Evaluation of Student Learning" (1971). Only when learning is at these different levels of cognition will a student be able to ask valid questions, interpret his knowledge and thus make use of his education in any new situation. Only then will the student be able to make decisions that are justified on the basis of his learnt knowledge. Learning at such levels will not only help one to be a master of what one has learnt; it will also help him to form basic concepts that are essential in any subject and also give him the necessary foundation on which he could have insights that help in higher cognitive thinking on any subject, including science. According to Chalmers (1980: 78),

> ...concepts acquire their meaning by way of a DEFINITION. Definitions must be rejected as a fundamental procedure for establishing meaning. Concepts can only be defined in terms of other concepts, the meanings of which are given... concepts derive their meaning at least in part from the role they play in a theory... .

It has been established by researchers that learning and memory are linked to different senses of perception. It is said that an average of 3 percentage of man's knowledge is acquired through his sense of touch. Of this, he retains only one percent. What one can perceive through his sense of smell is also 3 percent, but he retains one and a half percent of this in his memory. The sense of hearing is more useful as he can receive 13 percent of knowledge through it, but he is only able to retain 11 percent. Using his sense of sight man has the remarkable ability to retain 83 percent out of the 87 percent that he receives (Dreckmeyr 1988: 30). It has also been found that better learning and memory occur when more than one receptor organ is involved in receiving it in an educational situation. This is the reason for advocating the use of different methods of teaching involving various teaching aids, especially the chalk board and other visual aids.

Perception must give the learner the necessary mental picture of the subject, that can only happen when there is the understanding of the subject matter that is being taught. With understanding, students can develop basic concepts. Having developed concepts, students can associate them in new situations and make meaningful interpretation out of them. This will lead them to realise the usefulness of what they study in their daily life. Such learning process leads to meaningful learning. Knowledge learnt can be applied to any situation. By association, a student will be in a position to form abstract thought, which according to Kulpe's Wubeurg School of thought, is the highest form of thought, as it is something that has not been already observed (Dreckmeyr 1988: 31).

2.4 THE ROLE OF PRACTICAL WORK IN THE TEACHING OF PHYSICAL SCIENCE

Physical science, according to the dictionary definitions we saw previously, is concerned with analysing the nature and properties of energy and non-living matter. That means it is concerned with activities that form part and parcel of scientific investigation - doing practical work.

> An important general characteristic of the principle of physics since Galileo is the fact that it involves experiment. Experiment involves planned, theory-guided interference with nature. An artificial situation is constructed for exploring and testing a theory. Experimental practice of this kind was absent from physics before Galileo (Chalmers 1980: 119).

Chalmers (1980: 119) further comments that science, at some stage in its development, will involve a set of techniques for articulating, applying and testing the theories of which it is composed. As Ravetz (in Chalmers 1980: 119) puts it, "Scientific knowledge is achieved by a complex social endeavour, and derives from the work of many craftsmen in their very special interaction with the world of nature."

There is no doubt that science involves doing practical work and the growth of scientific knowledge has been due to such investigations or practical work. Scientific knowledge and its advancement have helped in the progress of technology that has directly helped man in enjoying its benefits. This has also helped to integrate science into the culture of various societies as shown in Figure 2.2 (e). However, it should be mentioned here that some technological advancements like weapons of war have not been unequivocally to the advantage of humanity.

Jardine (1982: 43) lists four reasons for doing practical work in schools. According to him, by doing practical in physics, it is hoped that pupils will

(a) have a better understanding of physics principles;

(b) be able to carry out simple investigations and solve simple problems;

(c) be able to discuss, by the spoken and written word, what they are doing and why, and

(d) develop a respect for experimental results and use experiments to test hypothesis.

Kerr (1963) (quoted by Hodson 1993: 88) presents the following ten possible aims for doing practical work in secondary school science:

1. To encourage accurate observation and careful recording.

2. To promote simple, common sense, scientific methods of thought.

3. To develop manipulative skills.

4. To give training in problem-solving.

5. To fit the requirements of practical examination regulations.

6. To elucidate the theoretical work to aid comprehension.

7. To verify facts and principles already taught.

8. To be an integral part of the process of finding facts by investigation and arriving at principles.

9. To arouse and maintain interest in the subject.

10. To make biological, chemical and physical phenomena more real through experience.

Hodson (1993: 90) mentions that the goals of practical work can be conveniently considered to fit into the following FIVE broad categories:

1. To motivate, by stimulating interest and enjoyment.
2. To teach laboratory skills.
3. To enhance the learning of scientific knowledge.
4. To give insight into scientific method and to develop expertise in using it.
5. To develop certain 'scientific attitudes', such as open-mindedness, objectivity and willingness to suspend judgement.

Hodson (1993: 91) asks a number of questions to initiate a critical appraisal of practical work. These questions are:

1. Does practical work motivate children? Are there alternate or better ways of motivating them?
2. Do children acquire laboratory skills from school practical work? Is the acquisition of these skills educationally worthwhile?
3. Does practical work assist children to develop an understanding of scientific concepts? Are there better ways of assisting this development?
4. What view/image of science and scientific activity do children acquire from engaging in practical work? Is this image a faithful representation of actual scientific practice?
5. Are the so-called 'scientific attitudes' likely to be fostered by the kinds of practical work children engage in? Are they necessary for the successful practice of science?

Hodson (1993: 85), quoting Nersessian (1989), confirms the need for practical work in science as follows:

> The predominant ideology among science educators is that hands-on experience is at the heart of science learning. As important as laboratory experience is thought to be, there has been little systematic analysis of just what can be achieved in the science laboratory.

However, much controversy exists as to the effectiveness of practical work in science and as to the answers to the questions on the aims of doing practical work in science. As far as motivation is concerned, though students could enjoy doing practical work in class, and perhaps develop some positive attitudes to science, several variables could cause several different reactions in different situations in class. For example, if the teacher is sympathetic, kind and helpful, then students doing their practical work will be encouraged, but if the teacher expects students to produce results and is not willing to understand their problems, they could be discouraged from doing practical work in class. There is evidence to show that there are many students who dislike doing practical work. It has also been noticed that what many students appreciate in a practical lesson is that such lessons are informal and they provide students with freedom of movement and offer opportunities to talk, interact, and socialise with their peers and teachers in an informal situation.

There is evidence to show that doing practical work in class does not necessarily help in the acquisition of skills. Development of laboratory skills, according to Hodson (1993: 94), "...has little if any, value in itself. Rather it is a means to an end - that end being FURTHER LEARNING." He elaborates on this, pointing that "...inadequate skills constitute a major obstacle for learning."

This is very true as far as teacher-training in Venda is concerned. Those teachers who are not familiar with scientific skills are the ones who are reluctant to use the practical approach to the teaching of science, even if facilities for doing experiments are found in the schools where they are employed after training.

Practical work could be done in three different ways:

1. Student laboratory work
2. Teacher demonstration
3. Small group interaction

Each of these has its own advantages and disadvantages. It is only with respect to the development of laboratory skills that individual practical work has an advantage over other teaching and learning methods. However, individual practical work is often counter-productive, leading to a somewhat distorted and incoherent understanding of scientific methodology (Hodson 1993: 95). Teacher demonstration has several advantages and it cannot give the skills development in individual students. It has been found that in spite of practical work done by students, they do not master the skills they are supposed to possess at the end of the course.

The early Nuffield course included widespread use of practical work. It was based on the notion that 'what you do for yourself, you understand.' However, there is abundant evidence that children, after doing extensive practical work, are not in a position to say what they have done, why they have done it and what they have found (Hodson 1993: 102). Contrary to the belief that doing helps in remembering, Driver (1983) (in Hodson 1993: 102) remarks that it is more likely a case of 'I do and I am even more confused' syndrome instead of the famous Nuffield phrase of 'I do and I understand.' Tasker (1981) (in Hodson 1993: 102) identifies several reasons for this unsatisfactory state of affairs:

1. Lessons are perceived by pupils as isolated events, not as part of a related series of experiences.
2. The pupil's purpose is different from that of the teacher. Often teachers do not state the purpose. Even when they do, they do not make sure that the pupils understand it. The tendency of pupils to construe either 'following the set instructions' or 'getting the right answer' as a purpose for a scientific task is evident in many classrooms.
3. Pupils fail to understand the relationship between the purpose of the investigation and the design of the experiment that they carry.
4. Pupils lack the prerequisite knowledge assumed by the teacher.
5. Pupils are unable to grasp the 'mental set' required.
6. The pupil's perception relating to the significance of the task outcomes are

not those assumed by the teacher.

Students are normally not involved in the designing and planning of experimental investigations. Curriculum planners do not involve the teachers in the planning process. The existing ideas of students or teachers are not considered. Because of all these, much of the practical work in class becomes unproductive. Teachers use laboratory work in class for obtaining information for confirming the content taught. This is directly the traditional inductivist view of science and the scientific method. This also results in misinterpretation of Ausubel's work on MEANINGFUL and ROTE learning that falsely equated rote learning with transmission/reception methods and meaningful learning with discovery methods (Hodson 1993: 103).

2.4.1 ENQUIRY ROLE APPROACH (ERA) TO DO PRACTICAL WORK

Small group interaction can take several different forms. They are a form of investigation or project. An enquiry or investigation is a piece of work that pupils can attempt in a school physics laboratory with the material available (Jardine 1982: 45).
According to this method, a problem is presented; for example:

> How do you think will the temperature of some cold water change with the energy supplied to it (heat)? Discuss this question and suggest a possible answer (or answers). Now devise an experiment to test your hypothesis and record what you did and what you found.
>
> Alternatively, the enquiries could relate to an application of physics; for example, "What would be the percentage increase in the cost of boiling some water in an electric kettle with the lid off rather than on?" Devise a way of finding out. Record your results and discuss possible uncertainties. Write a brief report on your investigation. (Jardine 1982: 45).

In this Enquiry Role Approach (ERA), each member of the team is given a specific task. However, the student can do other tasks as well, but has one responsibility. The advantage of this method is given in the statement of Olarinoye, quoted by Jardine (1982: 45-46):

> Much of education involves some sort of interaction among human beings. Although learning is an individual affair, it most frequently occurs within a social context. L. P. Bradford, a researcher of small-group methods, found that more complex learning can come about only through social interaction. The small group method grants more attention to the individual, the most important element in any learning system. One strength of learning in small groups is the variety of background experience of the students. Each group member benefits from the experience and different talents of the other members. The pooling of individual judgements tend to eliminate erroneous or inappropriate concepts and conclusions.

The proposed method of using improvisation for teacher-training is based on this method of Enquiry Role Approach that will help further in causing group cohesiveness and cause better self-development of the trainees when they work in small groups on projects using improvised apparatus.

2.5 MEANINGFUL LEARNING OF PHYSICAL SCIENCE

Meaningful learning of physical science depends on the successful teaching of the subject. Practical work has a role to play. Merely being in the laboratory and doing laboratory work there do not, by themselves, foster scientific attitudes: it is the quality of the experiences that students have there that is crucial (Hodson 1993: 96). The same applies to teaching. Many teachers are ill prepared to teach in any way other than teacher-directed learning styles. There are no comprehensive theories of teaching or the best method of instruction that will ensure success. Generally, the complete teaching style of a teacher has a great part to play in the success of a lesson. Science teachers could have three teaching styles, according to Eggleston (1976) (in Hodson 1993: 98):

1. Actor-manager type. These teachers emphasise teacher directed problem solving method of teaching.
2. Informers type who are the teachers who favour fact-finding and fact-acquiring in their teaching.
3. Enquirers type whose teaching is normally child-centred and lead the children to investigate and make enquiries in learning. The last type of teacher is favourable to teach physical science as it is child-centred and there is motivation to probe and investigate by the child to find facts by enquiry.

However, there is no one best method for teaching physical science. Besides, we should remember that different students respond differently to the same experience. It has been found that group activity has its own advantages as pointed out in the previous section.

Practical work has several disadvantages. Among them are noise, possible commotion, general indiscipline, students gathering too much of the information that prevents them from knowing the aim and goal of the practical. Practical work can be improved in a number of ways: by ensuring that students are aware of the central aim of the experiment, by cutting out some of the less crucial steps, and by using simpler apparatus and simpler techniques (Hodson 1993: 101).

Hodson (1993: 106) posits three major concepts of education in science. They are:

1. Learning science - acquiring and developing conceptual and theoretical knowledge.
2. Learning about science - developing an understanding of the nature and methods of science, and an awareness of the complex interactions between science and society.
3. Doing science - engaging in and developing expertise in scientific inquiry

and problem solving.

Science is a holistic and fluid activity, not a matter of following a set of rules that require particular behaviour at a particular stage. It is an organic, dynamic, interactive activity, a constant interplay of thought and action (Hodson 1993:119). In addition, there are (i) a kind of knowledge and understanding that can only be acquired by doing science, called 'Experimental flair', and (ii) a complex of affective attributes that are essential for the determination and commitment which, according to Polanyi (1958) (in Hodson 1993: 120), is called CONNOISSEURSHIP. This is intuition and it works in conjunction with rationalization. Polanyi (1958) and later Ravetz(1971) (according to Miller, in Wellington 1989: 51) refer to the scientists' knowledge of the method (or methods) they follow in solving scientific problems as being tacit, and the doing part of science has been equated somewhat with practising a craft. Constructing simple improvised apparatus from discarded materials to be used in investigation in physical science requires one to have the necessary knowledge and understanding and a tacit flair for doing or transforming knowledge into forms that have meaning. This can only be achieved if one has determination and commitment, and the connoisseurship that is like the 'green fingers' in gardening, which is essential for better teaching and learning of physical science in schools, especially in most schools in Venda , which have poor or no equipment.

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CHAPTER 3

IMPROVISATION AS A STRATEGY FOR THE TEACHING OF PHYSICAL SCIENCE

3.1 INTRODUCTION

Science as a subject is based on observation of changes in our surrounding and the steps that are taken to find out the causes of such observed changes. That is, it is centred around cause and effect. All the equipment - apparatus, instruments and machinery - used in science are meant to detect either the changes in the environment or the cause of such observed changes. Changes that take place around us are observed, either directly through our senses, or indirectly via the instruments that function as extensions of our senses. In the same way, our senses or the extensions of our senses - the instruments - could be used to find out the cause of the changes that occur around us. By noting changes and their causes, scientific knowledge, laws, hypotheses, and generalisations that form the subject matter in science are built up. Science is therefore intimately associated with the processes that are special to scientific investigations. Processes like observing, measuring, comparing, identifying, classifying, formulating relationship, predicting, hypothesising, verifying, designing an experiment, communicating scientific information, and making models are all parts of the scientific processes that one has to be involved in when doing science (Rogan 1980: 6). This is the reason why science is considered a doing subject.

Science however has content that can be studied, remembered, applied and manipulated to solve many problems. Many people view science as a body of knowledge - as the facts, figures and theories currently accepted by scientists. Many people also assume that attaining some familiarity with this knowledge is the first step towards achieving scientific literacy. In schools, this view of science usually results in teachers presenting standard facts in physics, chemistry, biology, and earth science in their classes (McCormack & Yager 1989: 47). Science education in most schools in Venda takes the form of teachers presenting scientific facts to students. Relatively recently (since the 1940s), our conception of science has expanded to include an understanding of science processes, or the skills scientists use to gather new knowledge. In science education this has encouraged the efforts to develop process skills in students (McCormack & Yager 1989: 47). Such process skills development has been a badly neglected area in science education in many countries, including Venda, at both the school and the teacher-training levels.

The study of the content of science that is cognitive in nature has to go hand-in-hand with the process aspect of science that develops the psychomotor skills of doing science. This is one reason for emphasising the need for doing practical work in science, because practical work is part of doing science and it helps to develop not only the cognitive but also the psychomotor aspect of science. Students who study science without doing practical work resort to rote-learning. They learn science without understanding it. Therefore, they cannot normally apply their scientific knowledge to any new situation. It is suggested that the effective teaching of physical sciences becomes possible once we understand that the conclusions of science are closely linked to the inquiry that produced them, and conversely, that the nature of a given inquiry depends upon the topic under investigation. "The choice is NEITHER facts and laws NOR inquiry and processes; it is BOTH facts and laws AND inquiry and processes" (Rutherford in Downing & Hamlyn 1980: 2).

Students who pursue science education in this manner by simply memorising facts, laws, formulae etcetera find that they cannot use and apply their knowledge of science to their daily life or pursue further education past the matric level. This is because their understanding of science is inadequate and they do not have the necessary psychomotor skills and insight that are important in applying science to daily life or to continue with further education. As a result, several students who leave school are unemployed, and those who go further have to repeat their science courses, many dropping out altogether from their science courses and some abandoning science for other subjects. From the researcher's experience and observation, this problem has been aggravated by the teachers who use the traditional telling method to teach science without trying to give an insight into the processes of science and helping the students to develop the necessary basic concepts in science.

Science can only be appreciated when students are involved in appropriate practical work, because only then can they develop the necessary skills, abilities, knowledge and attitudes that are essential for a proper knowledge and understanding of the subject. Such knowledge and understanding will enable them to form the basic concepts in science. According to McCormack & Yager (1989: 47), science should not be limited to content and process alone because as shown in Figure 2.3, there are five domains of science education and "...science education must encompass ALL these domains if it is to help students attain the level of scientific literacy demanded by today's society and tomorrow's needs" (McCormack & Yager 1989: 47).

The first domain (Knowing and Understanding) has been concerned with the traditional content of science that includes scientific information, facts, concepts, laws, hypotheses and theories. It also includes knowledge of the history and philosophy of science (McCormack & Yager 1989: 47).

The second domain (Exploring and Discovering) is concerned with the processes of science. By using this process approach, students have a chance to learn to think and work as scientists do. In doing so, they use both the psychomotor or manipulative and the cognitive skills. Students in Venda have generally not had a chance to develop this domain. Their science learning usually stops with the first domain of gathering scientific knowledge and a limited understanding of the subject.

Besides the first two domains, McCormack & Yager (1989: 48) mention the need for developing further domains that are important in learning science. The third domain (Imagining and Creating) is considered very important because it develops abilities like

> ...visualizing, or producing mental images; combining objects and ideas in new ways; producing alternate or unusual uses for objects; solving problems and puzzles; fantasizing; pretending; dreaming; designing devices and machines; and producing unusual ideas (McCormack & Yager 1989: 48).

This should indeed be the ultimate goal of science education. Scientific discoveries are possible when the scientists operate in this exploring and discovering domain. To encourage the attainment of this goal, students should be encouraged to get involved in scientific projects, especially by using simple home-made equipment and apparatus. This very core function in science education is served by improvisation of apparatus.

The fourth domain (Feeling and Valuing) is an attitudinal domain. Though it is primarily an affective domain, it is very valuable as it includes

> ...developing positive attitudes towards science in general, science in school, and science teachers; developing positive attitudes towards oneself, or an 'I can do it' attitude; exploring human emotions; developing sensitivity to, and respect for, the feeling of other people; expressing personal feeling in a constructive way; making decisions about personal values; and making decisions about social and environmental issues (McCormack & Yager 1989: 48).

The last domain (Using and Applying) is considered to be essential to give meaning and direction to the study of science.

> It seems pointless to have any science program that does not impart to students information, skills, and attitudes that can be used in the students' everyday lives. ... Some of the dimensions of this domain are seeing instances of scientific

> concepts in everyday life experiences; applying learned science concepts and skills to real technological problems; understanding scientific and technological principles involved in household devices; using scientific processes in solving problems that occur in everyday life; understanding and evaluating mass media reports of scientific developments; making decisions related to personal health, nutrition, and life style based on knowledge of scientific concepts rather than hearsay and emotions; and integrating science with other subjects (McCormack & Yager 1989: 48).

This outlook of science education is very important because it forms a kind of intrinsic motivation for students to learn the subject as they could see its use and value to life situations. Unfortunately, the science teachers were themselves not exposed to this domain when they were students, and so they cannot use these valuable domains to create the interest in students that will be the motivating force for the students to develop a positive attitude towards learning science.

The application of the process approach, especially by using improvised apparatus in which both the students and the teachers work as scientists to build basic science concepts and skills in science, is very useful. It helps in the development of all the five domains of science education. Besides this, "...by letting students view science from only one or two domains, we may be depriving them of the opportunity to see the richness of science" (McCormack & Yager 1989: 48).

3.2 IMPROVISATION IN SCIENCE TEACHING

An imaginative teacher is not satisfied with teaching a subject like physical science by the textbook method only. There are several experiments or projects that can be done in class. This is possible even in the absence of equipment or laboratories in the school. The teacher encourages the students to do projects on their own, using simple equipment found at home. This enables the students to understand science content by doing and in that way build their knowledge of the subject matter with understanding. By doing so, the subject also becomes meaningful as it is not restricted anymore to the class or the laboratory; it is relevant to the student for he can do things that are scientific even at home or elsewhere without any sophisticated equipment.

The term 'improvisation' is defined as the act of making or providing from available materials (Reader's Digest Great Illustrated Dictionary 1984: 856). This definition, though not very elaborate, is a comprehensive one. "The act of making or providing" and "available material" are two key phrases in this process. Both these are essential for improvisation to take place. Readily available cheap material from the environment should be used for making or providing equipment or apparatus that could make the science lesson interesting, leading to student interest, involvement and understanding of the subject. The remark made by Berluti (1989: xxii) regarding improvisation is worth noting here:

> Improvisation should not be regarded as a cheap substitute of proper laboratory equipment; Many great masters of science used improvised apparatus and many great discoveries have been made with improvised equipment.

Any available material could be used to improvise apparatus for experiments in teaching science. It is a method that can give confidence and competence to teachers and make science lessons meaningful and related to the environment of the students. Thus science can be linked by this method to the society, the environment and other subject disciplines and the students can be made to understand its usefulness to man in general and to the society and the world at large.

3.2.1 WHAT IS A TEACHING STRATEGY?

Teaching is a complex task as it is concerned with the imparting of knowledge to students.

Students who are taught undergo a change that is not visible from the outside. Teachers prepare and plan their lessons, use different methods and various teaching aids and generally motivate student learning. Tests, questions, examinations and other forms of evaluation help to get some feedback about student learning.

Teachers use various strategies or approaches and methods to help student learning. For this to happen, planning is essential. A teaching strategy can be viewed as an extensive teaching plan which includes all elements that will help instruction and thereby bring about student learning. Traditional teaching methods and techniques, which refer only to some facets of the teaching-learning process, may be considered part of a teaching strategy (Dreckmeyr 1994: 67). "Teaching strategy is a generalized plan for a lesson that includes structure, desired learner behaviour in terms of goals of instruction and an outline of planned tactics necessary to carry out the strategy. The lesson strategy is a part of a larger development scheme of the curriculum" (Stone & Morris (in Sharma 1992: 51)). Teaching is often considered an art and using teaching strategies helps in developing one's skills of teaching. It requires the knowledge of the content or the subject matter, teaching method, use of teaching aids and the techniques of teaching. All these make teaching interesting and effective. It is left for the teacher to choose the methods and techniques used in teaching, depending on such factors as the learning objectives, learner abilities, teacher interests and available resources.

Teaching strategy could be of two kinds depending on whether it is teacher-centred or student-centred. The traditional method of telling facts that students learn without question is typical of the teacher-centred strategy. This is also called the Autocratic style (Sharma 1992: 52) that is content-centred. The recent trend however is more towards the use of the permissive style that is less conventional (Sharma 1992: 56). Though it is called the student-centred approach, both the teacher and the student are active in this strategy and it seems less conventional, it creates situations for better student-teacher interactions and encourages student creativity. As this strategy is centred around the student's needs and desires, teachers are encouraged to specify their objectives when planning a lesson in student behavioural terms. Education is thus seen as the development of joint understanding (Wellington 1989: 80).

According to Dreckmeyr (1994: 67) teaching strategy could also be divided based on two extremes of a continuum. At one extreme end or pole is "the inquiry and/or discovery strategies." At the other pole are the expository strategies, in which the teacher merely supplies the information. Teachers usually blend these two strategies (Dreckmeyr 1994: 67). The traditional teacher who uses the teacher-centred approach teaches science using the predominantly expository strategy, as with the science teachers in Venda. However, a teacher who would like to use the student-centred approach would predominantly use the inquiry strategy in teaching science.

3.2.2 WHAT IS IMPROVISATION?

Improvisation, we saw, is the "act of making or providing from available materials" (Reader's Digest Great Illustrated Dictionary 1984: 856). According to the Odhams Dictionary of the English Language, to improvise means "... to compose and perform on the spur of the moment without previous preparation; to rig in a makeshift way, to construct a rough or approximate copy of an object out of material or other objects at hand" (in Dreckmeyr 1994: 123). Tsuma (1985: 48) defines improvisation as follows:

> ...the process of consciously searching the student's immediate environment for materials and their appropriate arrangements in order to generate familiar events for the student's sensory perceptual experience antecedent to, or concomitantly with and for purposes of, instruction.

Improvisation could be done in two different ways. "The first is to compose and perform on the spur of the moment. ...The second area of improvisation has to do with the construction of an approximate copy of an object out of materials at hand. In science teaching this refers to constructing improvised equipment and using such equipment to improvise experiments, approximating the prescribed experiments where possible" (Dreckmeyr 1994: 123). Improvisation can be used as one of several strategies available for teachers to teach science. It can also be used with conventional methods. In writing a lesson plan for science, improvisation can be included as one way of introducing the process approach. In this case, improvisation can also be considered a method in teaching science. It is basically a student-centred approach and encourages the student towards further inquiry and discovery. It does not help to develop only scientific knowledge and process skills but also the other domains of science education, such as imagination and creative thinking; human feelings, values and decision making skills; and the all-important capacity to apply ideas taught in school to their experiences that are outside the school (McCormack & Yager 1989: 48). The five domains of science education mentioned by McCormack & Yager (1989: 47) could all be achieved when improvisation is used as a strategy for teaching physical science.

Improvisation in science teaching also involves "...using those unexpected and unplanned opportunities intuitively to demonstrate a concept or principle to pupils..." (Dreckmeyr 1994: 123) and can also include metaphors, models, similes, and simulations used very often by experienced teachers to illustrate their science lessons meaningfully in class. According to Wellington (1989: 2), Selley has shown the value of philosophy in guiding practice. He argues that science teachers must pay great attention to metaphors, analogies, and models used in the process approach to science teaching. The success of using improvisation as a teaching strategy will largely depend on the experience of the teacher and his exposure to such ideas; it is not something that the teacher can be taught or trained in rigidly. What is essential is for teachers to be exposed to such possibilities and be made aware of the use of such strategies whenever it is suitable (Dreckmeyr 1994: 123-124). However, for this dissertation, improvisation is specifically restricted to science equipment and apparatus that can easily be made by teachers (and students with the guidance of teachers) for teaching and learning science at the secondary school level.

The process of improvising and learning to improvise is more important in teacher-training than the actual use of improvised apparatus and equipment. The advantages of this exercise are many and varied, and a rich learning experience is gained at every stage of improvisation. It opens the eyes of the teachers, especially in imaginative and creative thinking. It also helps the process of designing and improvising equipment and apparatus leading to turning out the much-needed teachers as technicians rather than scientists as teachers.

3.2.3 IMPROVISATION AS A STRATEGY IN SCIENCE TEACHING

According to Lewin (1989: 74), secondary school science is "taught badly by underqualified teachers struggling with curricula that are urban-biased, scattered with examples unfamiliar and inaccessible to the bulk of the students." This results in the problems of frequent under-utilisation of specialised facilities like laboratories and workshops, the shortage of quality science teachers and the unexpectedly small student enrolments (Walberg 1991: 31). These are all very true of the secondary school science education in Venda. One may even be tempted to think that these authors are referring to the state of science education in Venda and not to that in America - a first world country - about which these comments were written. As far as science education is concerned,

> Americans, ...still can't comprehend and discuss scientific matters intelligently. Nor, as John Dewey hoped 75 years ago, have Americans acquired scientific habits of mind such as evaluation of evidence, deductive reasoning and quantification... most students lack the ability and special effort required to prepare for advanced studies. Nor, ...do they require it. ...though they mastered in school some factual information they soon forget (Walberg 1991: 32).

Setting attainable goals like science knowledge, understanding, application and appreciation may all be reasonable goals to aspire for. It is by aiming at high levels of mass scientific literacy rather than by trying to make students scientists and mathematicians that Japan has come to the topmost position today in many science and mathematics achievement-score comparisons (Walberg 1991: 32). If one is thinking of science for all, then it becomes necessary to argue for a process-based curriculum (Wellington 1989: 9). From the foregoing, there is evidently a need and a place for improvisation in teaching science and that the use of improvisation in teaching science in schools could possibly produce better mass scientific literacy that is essential in making science interesting, stimulating and sometimes even amusing to the student. This will then make science taught at school not terribly strenuous, and will hopefully bring in scientific literacy to the masses. To effect this change, teacher-training becomes important because "...the relative failures of the curriculum packages in the '60s and the '70s are often ascribed to inadequate attention being paid to teacher-education in relation to the changes in the science curriculum" (Fensham & Northfield 1993: 67). *The Secondary School Curriculum Review in England and Whales* (1987), notes that "...the professional development of science teachers is the critical factor in improved science education" (Fensham & Northfield 1993: 67). Proper teacher-education is therefore essential for better teaching and student learning of science.

Improvisation, when used as a teaching strategy, helps student learning because of several reasons. The strategy is student-centred. It uses simple material discarded at home and workplace and so is also environment-centred and society-centred. Its use points out to the student that the things in the environment that one does not consider useful can be used in studying science. The student also sees the advantages of the knowledge and the experience possessed by the people in the society, from whom material and knowledge regarding aspects of science could be obtained. Thus the student sees science as a subject that is relevant to himself and to his environment and the society in which he lives. Science, that was so far an abstract subject, suddenly turns out to have meaning and use to the student. It is no more a subject confined to the pages of the textbook or to the four walls of the science classroom or the laboratory. The student who is taught science by the use of improvisation as a strategy is motivated. He asks probing questions and by his enthusiasm and interest finds out many facts by himself. The teacher plays a secondary or subsidiary role in teaching, as the student is motivated enough to go ahead on his own. This strategy, besides the advantages mentioned here, has the greatest advantage in those schools where there are no equipment or laboratories for science teaching. By using this strategy, the teacher can still make the students function as budding scientists involved in exploring and investigating, and doing science using the process approach. "Those who argue for 'process' seek to involve pupils more actively in science. This is a welcome development and some work it promotes is a great improvement on previous practice" (Wellington 1989: 58). As a result of this, students learn to see the advantages of doing science. They develop the right attitude towards science and science projects. This helps in developing all the five domains of science education mentioned by McCormack & Yager (1989: 47).

3.2.4 CONSIDERATIONS FOR IMPROVISING EQUIPMENT AND EXPERIMENTS

To improvise equipment and experiments, one has to be open, receptive and observant. "In teaching children science we are helping them to internalise the procedures and standards of the scientific community. We are assisting the child to construct for herself a mental representation of the scientific ways of working and judging" (Wellington 1989: 60). Observation, an important process concerned with doing science, plays a vital role in the process approach to learning science. Many items discarded at home, in the workshop, in garages and other places become useful in constructing simple equipment and conducting experiments without a laboratory. It is also necessary to be aware of the things that are being used in our daily life and relate these to what is learnt in the science classroom. A knowledge of all metals, non-metals, acids, alkali, organic and inorganic compounds that are usually available at such places as the home, the pharmacy, the supermarket and the hardware shop, could be useful in employing this teaching strategy effectively. For example, if one has to construct a home-made soda fire extinguisher, a knowledge of commonly available acids, carbonates and bicarbonates at home will be necessary before starting to collect materials, designing and construction. Another example is where a teacher would like to show to his students that only balloons filled with a gas which is lighter than air, like hydrogen, will rise on its own, and not a balloon filled with ordinary air. He could prepare hydrogen at home using the following method:

> Put several pieces of aluminium (or zinc) foil into a litre empty Coke bottle. Add some caustic soda (Sodium hydroxide) and pour nearly boiling water into this mixture. Vigorous bubbling of gases can be seen. When some gas has escaped (why?), pull the mouth of a balloon over the mouth of the bottle and let it stand. It will be noticed that the balloon starts getting inflated as it gets filled with some colourless gas. Once the balloon is sufficiently large, tie its mouth with a thread after removing it from the bottle without allowing the gas in it to escape. Now hold on to the end of the thread and let go the balloon. It could be seen that the balloon rises on its own. But for the thread holding it, such a balloon would have continued to rise in air and would be lost very soon. In this experiment, the concept of some metals like zinc and aluminium reacting with alkali to liberate hydrogen gas is used. (The reactants formed are sodium zincate or sodium aluminate respectively and hydrogen gas). The litre Coke bottle prevents the frothing soapy alkaline solution from entering the balloon as the bottle used is quite tall. This bottle is also suitable here as it is made to stand both high pressures and high temperatures. All this simple knowledge about household materials helps in selecting suitable equipment for experiments that are fairly safe to conduct even at home, and the important aspect is that such experiments work quite well.

The following list of useful points may be considered when making improvised equipment and conducting experiments (Dreckmeyr 1994: 124):

* Make use of materials that pupils are familiar with, for example, ordinary drinking glasses, instead of test tubes or glass beakers, and an iron nail as the soft iron core in an electromagnet.

* Keep the apparatus as simple as possible.
* Students should be actively involved by collecting the materials, constructing the apparatus and presenting demonstrations of improvised apparatus and experiments.
* Improvised apparatus and experiments should be tested beforehand to make sure they work.
* The use of improvised apparatus and experiments is not limited to teacher demonstrations, but could just as well be used in practical work in groups or by individuals.
* Wherever possible, improvised experiments should be followed up by the prescribed experiments, using more sophisticated apparatus so that the child will also become acquainted with laboratory equipment and materials.

3.2.5 MATERIAL FOR IMPROVISATION

Materials that could be used for improvisation are usually those that are easily available, for example, at home, in the kitchen, the workshop and the repair shop. Materials so obtained could include those that are normally discarded, like the disposable syringes and plastic saline tubes from the hospital, empty milk bottles and drinking straws from the home, magnets and coils from the radio repair shop, winding wires and carbon electrodes/brushes from the auto electrician, lead metals and old car/motorcycle tubes from the tyre repair shop. For this, it is worth looking at the various sources from where several materials for the use in teaching science by improvisation could be obtained (Appendix I).

Several such materials from various places could normally be obtained free of charge most of the time. A teacher-trainee who had to build a simple galvanometer and other electrical items for a project assigned to him was in a position to obtain, free of charge, considerable quantity of enamelled winding wire from a shop dealing with the rewinding of armatures of dynamos and motors. Incidentally his project at the National EXPO for Young Scientists Competition (1993) was adjudged a silver medal winner - the first medal for Venda since it joined the EXPO family in 1992. The shop owner was pleased when he was informed of the outcome of the student-teacher's performance at the National EXPO. A tyre repair shop happily gave the researcher several new pieces of lead (though the researcher asked only for the old discarded ones) used for balancing of wheels to be used by student-teachers in their projects. A cut glass dealer in town willingly not only gave pieces of glass and mirrors that could be useful for experiments, but was good enough to cut them free of charge to the trainee's specification. These are just a few instances where members of community are quite willing to help enthusiastic teachers in their teaching of science. One has to remember at this stage the saying in St Matthew: "Ask, and it shall be given you; seek, and ye shall find..." (The Oxford Dictionary of Quotations 1979: 65). Having a positive attitude and a pleasant disposition will pay dividends when one asks for help.

Materials obtained from such places can be used for science teaching if the science teacher is knowledgeable and experienced in using them in the class for effective teaching. That means the teacher has to improvise and make his own science equipment. To accomplish this, knowing the sources and resources from where useful material could be obtained is important. Having obtained these materials, the teacher should have the know-how, experience, aptitude and ability to do the necessary improvisation of the apparatus or the equipment. Teachers and teacher-trainees generally cannot apply their knowledge of science to doing practical work outside their classrooms and laboratories (Gallagher 1991: 132). Therefore, teacher-trainees cannot comprehend that practical work can be done outside a laboratory. This is one reason why teachers always want a laboratory to do experiments. For many science teachers, the normal classroom is not a place to do any experiment. Teachers who get the necessary experience in making, handling and using improvised apparatus can overcome this problem in the teaching of science.

At times, it may be necessary to pay a nominal fee for the material obtained for an experiment involving improvisation. Such expenses could normally be recovered from the school funds, if the teacher arranges with the principal. However, enthusiastic and dedicated teachers may themselves pay out of their own pocket for such material. They would do this in the interest of making their science lessons meaningful and interesting to their students. Such material will be useful in teaching science by turning out several simple apparatuses to illustrate many science concepts, principles and laws by using the doing or process approach with the students while teaching science.

> For every country, there is a range of ways of providing resources and equipment for practical science, which will include: improvisation by teachers in school; in-service workshop for equipment production; nationally produced equipment; and imported equipment. .... Improvisation by inventive teachers developing ideas for apparatus and experiments in their own work environment is hardly a new phenomenon - it is a very creative activity, traditionally close to the hearts of physics teachers in particular, and to famous scientists like Rutherford who coined the phrase 'string and sealing wax' to describe certain approaches to experimentation! (Allsop, in Woolnough 1991: 37).

Improvisation of simple equipment is a worthy endeavour because of the following reasons:

1. It is cheaper, so that there is more apparatus available for individual or small group experiments, besides teacher demonstrations.
2. Concern over loss, breakage and repair is reduced; therefore equipment is more frequently used.
3. Students are made aware of scientific principles applied to everyday thinking, not just those associated with special apparatus imported from abroad.
4. Attention is drawn to the need to estimate accuracy.

5. Students can see where inaccuracies arise and can see the need for more sophisticated designs for many purposes.
6. A classroom can often be used if a laboratory is not available.
7. Simple equipment encourages students to make good use of local resources, and enhances self-reliance.
8. Simple experiments often demand an understanding of basic principles rather than the following of a set of complex experimental instructions (Allsop, in Woolnough 1991: 37-38).

The above are all very good reasons for using improvisation as a method of training teachers in Venda. This method is advantageous as it gives the teachers the much-needed and essential background training in the use of equipment and in understanding basic principles of science. For effective learning of science, it is essential that it be experienced (UNESCO 1960: 7). By using the process of improvisation, teachers and teacher-trainees are provided with the necessary experience that enables them to understand, especially through experience, the basic principles of science. This enables them to teach science effectively.

3.2.6 THE ACT OF MAKING OR PROVIDING

For improvisation to take place, the act of making or providing equipment and conducting experiments from available material has to be mastered by the teacher. To do this, the teacher should have thorough knowledge and understanding of what he is undertaking. The teacher should have sufficient manipulative (psychomotor) skills and experience to construct the equipment and do the experiments. By doing simple demonstrations, what is an abstract idea in theory becomes clear, resulting in the formation of concrete concepts. However, there could be many a problem in making an improvised equipment work. The effort put in to remedy problems while doing experiments are worthy experience for teachers. As an example, take the case of a teacher who tries to demonstrate Newton's

First Law of Motion using the following simple experiment:

> Place a sheet of paper flat on the table close to its edge and place a glass of water in the centre of the paper. If the paper is pulled slowly away from the table, the glass of water is seen to move along with the paper. Therefore the glass is liable to fall and break. Now if the paper is suddenly pulled with a sharp movement away from the table, it will be noticed that the glass of water continues to remain in the same position on the table. The glass of water remains without any movement at all although the paper is in the hand of the person who pulled it.

A demonstration of this kind using improvised equipment can be followed by suitable questions in class that can lead to the proper understanding of the principles involved. This will help to clarifying Newton's First Law. There are several other experiments that can be done to illustrate this principle. Teachers must use their imagination, try them out and encourage students to try such experiments on their own at home too. It is also necessary that teachers ask questions regarding the possible applications of the principles learnt in our daily lives.

In doing this experiment, a teacher may experience several difficulties that could result in not getting the expected result. For example, if the paper is wet or if it is crushed, the result may not be the same. There is also the act of pulling the paper that could influence the result. A teacher trying this on his own the very first time may possibly get disappointing results. On repeating the experiment the second time the teacher will try to succeed and in the process learn more about the act of making or doing, which is an important aspect of science education. "Most teachers will have found that their first attempts at doing investigation with a class have been, to a greater or lesser extent, a disaster, and become convinced of their value only through persevering to the vast improvement in the second and subsequent experiences" (Wellington 1989: 121). This helps in the imagining and creating domain that McCormack & Yager (1989: 47) listed as the third domain in science education. It is essential for teachers to try out experiments ahead of time and find out ways of making them work well. Through the mistakes made during such trials, further, finer alterations could be made that will ensure the success of the experiment. This kind of experience itself could be a useful learning exercise for the teacher. It will help the teacher attain all the five domains of science education as given in figure 2.3. Attaining all these domains is essential for proper science education. The remarks made by Jansen (1991: 22) to help science teachers to improve their teaching of science is worth recalling here. He asks the teacher to

> ...be dramatic! Be a real actor! Always perform experiments like a professional showman. Show your pupils how much you enjoy it all. If you are not sure of the experiment, practise it beforehand so that you are perfect on the day. Pretend to be helpless sometimes. This will encourage the pupils to help you.

Teachers working together in workshop groups have resulted in the production of several local science equipment in many countries, according to Allsop (Woolnough 1991: 38). There are several advantages in doing this. It reduces dependency on imported science equipment. It produces equipment of consistent quality. This involves teachers, teacher-educators and curriculum developers at the design stage. These practitioners produce equipment closely related to contemporary science curricula in use in the country. All these form commercial enterprises (Allsop, in Woolnough 1991: 38). The use of improvisation in schools and in teacher-training institutions can help the development of such kits of apparatus along with the development of suitable curriculum packages to suit the needs of the country. It can also help to develop teachers' guides and student work sheets, such as the Science Education Project (SEP) material in South Africa, the Science Equipment Production Unit (SEPU) of Kenya and the ZimSci kits for both teacher and student practical work in Zimbabwe, to name a few from this continent.

3.2.7 ADVANTAGES OF USING IMPROVISATION IN TEACHING SCIENCE

Pupils should be able to master useful practical skills which they would apply in

> life in various ways. They should adopt a scientific attitude and approach; they should observe, collect information, draw conclusions and apply what they know (Allsop, in Woolnough 1991: 32).

To achieve these aims, laboratories are essential, because "the laboratory is a unique facet of science education" (Tamir,1989 (quoted by Allsop, in Woolnough 1991: 31)). Without laboratories, one alternative that can be used to achieve those stated aims is improvised equipment. "We need to build up habits by problem-solving, through experience, and enable the students to build up a store of tacit, craft knowledge with which they can confidently build and experiment" (Wellington 1989: 121). Since science is a doing subject, students must get a first-hand knowledge and possibly a hands-on experience of not only seeing, but also doing, thinking, manipulating and functioning as budding scientists do:

> A technologically-oriented, democratic society cannot exist with large sections of its population ignorant of science and technology. Attitudes, skills, reasoning abilities and knowledge from science are a prerequisite to a sense of control over human destiny on the part of the populace (Yager, 1984 (in Ogens 1991: 203)).

By providing a solid scientific ground in primary and secondary general education, not only the foundations for further scientific study by specialists can be laid, but also a scientifically literate general population that is well prepared to live in an age of science can be produced (Walberg 1991: 34-35). According to the work of Layton (1989) Nigerian secondary school students with favourable attitudes towards scientists and science in society are most likely to continue their study of the subject. He also finds that students avoid science courses if they see the subject as unenjoyable or too difficult (Walberg 1991: 41). These are reasons for saying that science is an important subject and therefore has to be made a meaningful subject to students. Because students value activities over other forms of instruction and prefer divergent to convergent lessons, a conscious effort must be made to identify content that has some meaning within their everyday lives. Further, this content should be relatively concrete and subject to physical manipulation (Piburn & Baker 1993: 403-404). To achieve meaningful and concrete understanding of science, teachers and teacher-trainees must themselves have experience using science concepts and processes in real world situations (Yager 1991: 97). The use of improvisation in teacher-training has its value: it can help teachers achieve these objectives. As Pell (1988: 63) points out, both the theory and the practice should form the necessary complements in science teaching.

As a result of teacher-training, better student learning should take place. It is known that students, when given more time, can benefit by their science education. However, according to Walberg (1991: 40),

> ...those that start ahead gain at a faster rate, which results in what has been called MATTHEW EFFECTS, the academically rich getting richer, originally noted in THE BIBLE: 'Whoever has will be given more, and he will have an abundance. Whoever does not have, even when he has, will be taken from him' (Matthew, XIII, 12; 1985: 1461).

In bringing about student learning, it is the duty of the educators to alter the quality of instruction or the methods of teaching (Walberg 1991: 44). Well-implemented conventional teaching should be retained for improving education. Innovative methods can be recommended for cautious experimentation and trials where they seem particularly suitable, feasible, and cost-effective. They might be especially recommended as a supplement rather than a substitute for conventional teaching that needs to be systematically improved (Walberg 1991: 44). Using improvised equipment in the teaching of science could well be a supplementary method even if there are facilities for using the conventional method of teaching science because of the many advantages conferred on its method.

Mastery learning is another method that combines "effective elements of instruction with suitable amounts of time" (Bloom (1982) as quoted by Walberg 1991: 44). Japanese students are taught mathematics by the Kumon method (after its inventor Toru Kumon, in the mid-1950s) who believed that "... the most solid progress can be made when facts and skills at one level of difficulty are thoroughly mastered before going on to another" (Walberg 1991: 45). This is not only true of mathematics, but of science and all other subjects as well, because learning is hierarchical, and it is the duty of teachers to identify what learners can do by themselves and go from there to maximise their ability to go further. "Accordingly, teachers should set up scaffolding for building knowledge but remove it when it becomes unnecessary"' (Walberg 1991: 45). Such scaffolding for concrete experience and hands-on experimentation can be provided in a science class by improvisation by the trained science teacher.

Teachers should help in the independent development of children by encouraging self-monitoring, self-teaching, or metacognition to foster independence by providing them opportunities to plan their own lesson, allocate time for studies and review their progress. This is also possible when the method of improvisation is used in teaching science. For the accomplishment of this objective, we may consider the three phases: "...(a) modelling, where the teacher exhibits the desired behaviour; (b) guided practice, where students perform with help from the teacher; and (c) application, where the student performs independently of the teacher" (Pearson (1985) in Walberg 1991: 45). All these steps could be employed when improvisation is used for training science teachers. Such a training will give them the necessary exposure and experience in handling and making apparatus and using them to see how they work. Such teachers work on their own, having had the experience of constructing apparatus for experiments and thus widening their outlook of science and relating it to the environment from where both the material and the resources for improvisation are obtained. Experience in improvisation gives the teacher the needed understanding, skills and abilities and the confidence that enables him to do the experiments using such apparatus. This hands-on activity helps to emphasise science processes and skills. This experience helps students to socialise and develop the necessary scientific skills and attitudes that are important components of science education.

As science equipment is not readily available in several schools in Venda (and many other similar disadvantaged areas of South Africa), improvisation is a way of 'filling the gap' to provide the necessary science experience in teaching by doing, rather than simply talking with the aid of the chalkboard. There is yet another advantage in using this method of teaching science: "... improvisation connotes the use of apparatus constructed from locally available material resources as a means of keeping educational expenditure low" (Tsuma 1985: 47). Minimising the educational expenditure is a very important consideration especially in the context of a developing country like Venda, where some schools have very little science equipment and only a handful of schools have the luxury of science laboratories. This is an important consideration especially when funds are limited and several schools have to be equipped with science laboratories. Because of improvisation, meaningful teaching and learning of science can often take place even in schools that have no laboratories. This method brings about the involvement of the student's immediate environment and thereby brings 'meaning' in teaching as proposed by Beeby (in Tsuma 1985: 48).

Dreckmeyr (1994: 124-125) lists several advantages of improvisation as a strategy for teaching science:

* It makes the subject more real to the child by relating the subject matter to concrete experiences of the child.
* The child will realise that his scientific activities can be traced back to everyday situations from which specific aspects have been abstracted.
* It stimulates the interest and curiosity of the child.
* It creates a spirit of enquiry and develops a 'scientific' attitude.
* The child is actively involved by collecting materials and constructing apparatus.
* The child can repeat what was demonstrated in class at home on his own.
* It will clarify the theoretical aspects of science for the pupils and thus

enhance comprehension.

* It makes science teaching more enjoyable and stimulating for the teacher.

3.2.8 IMPROVISATION AND THE REALISATION OF DIDACTIC PRINCIPLES

In the teaching of physical science, teachers normally use several didactic principles to make the lesson effective and attractive to the students. A knowledge of the different principles of teaching will certainly be useful to all teachers. They will then be able to select the one most effective for a particular lesson planned. Experienced teachers have a way of using different principles in the same lesson, sometimes in combination with other principles to the best advantage of student learning of the subject with understanding and insight. However, there is no definite formula or recipe for the successful teaching of science using different principles of teaching. Success in teaching generally depends on the ability, ingenuity and imagination of individual teachers. One can only bring to the notice of the teacher the characteristics of the various didactic principles. It is left to the individual teacher to use these principles under suitable circumstances for the best results. In the following sections, the researcher hopes to highlight five of the didactic principles which favour and enhance the use of improvisation as a teaching strategy. This will be done keeping in mind the five important domains of science education proposed by McCormack & Yager (1989: 47).

3.2.8.1 PRINCIPLE OF MOTIVATION

Motivation is the desire to know or learn more about what one is doing and it arises out of a need for learning, which forms the fundamental step in any education. The need for education must drive a student to want to learn. Motivation could be internal (intrinsic) or external (extrinsic). Without motivation, no useful learning can normally take place.

Dreckmeyr (1994: 29) observes that the failure of many pupils is simply because they are not motivated or driven from inside to learn; not that they are not capable or talented enough to learn. Another generally accepted factor in effective teaching depends on the motivation of both the teacher and the learner. Therefore, the special task of encouraging the student to learn and master the new subject content depends heavily on the teacher.

Improvisation encourages student involvement in the learning process in an active way: it allows the student to participate in the learning process as he helps the teacher in various ways, like in the collection and construction of equipment and apparatus. Such active involvement in the lesson makes the students interested in the lesson. This is the first step needed for learning to take place in any subject.

> Credible results, whether obtained by experiments, the completion of a graph or simple calculation, provide satisfaction because a goal has been achieved which might even be applied in one way or another. The resourceful physical science teacher should exploit this inquisitive search for excitement and suspense to keep the pupils' interest and motivate them to learn (Dreckmeyr 1994: 30).

There are many other factors that could contribute towards motivation. Some of them are thought-provoking and challenging questions and problems; assignments that are not too difficult or too easy for the learner's cognitive level of learning; active involvement in the lesson by allowing students to participate in experimentation, demonstrations, and improvisation of apparatus and experiments; relating the subject matter to concrete experiences of the student; making the subject matter and the lesson as interesting as possible, not necessarily teaching only interesting subject matter (Dreckmeyr 1994: 30). Improvisation, when used in the teaching of science, can cause motivation in all the above-mentioned various ways.

3.2.8.2 PRINCIPLE OF ACTIVITY

In physical science, as a predominantly experimental subject, the guideline of activity is a prerequisite for teaching this subject effectively. According to the guideline of activity in the teaching of physical science, the pupils should be given the opportunity to apply scientific approaches and learn how to master scientific processes such as observation, measurement, interpretation of data, formulation of hypotheses, experimenting and so on (Dreckmeyr 1994: 34-35).

For student learning to take place, motivation is essential. But motivation is not sufficient to cause learning in students. It is important for students to actively take part in the learning process. If they are not active while learning, the lesson may turn out to be teacher-centred, instead of it being student-centred. Active learning by itself will be a motivating force for students to want to know more, and as a result better learning will follow. During active learning, students, instead of remaining inactive like empty vessels waiting to be filled with knowledge, should be actively engaged in the learning process by taking part in appropriate activities that lead to learning (Hodson 1993: 125). These could be mental activities concerning cognition at different levels or a combination of mental and physical activities as happens with the activities in a science classroom where students are involved in doing their own projects. It not only involves the cognitive aspect, but also the psychomotor aspect of student learning. Students who are involved in helping the science teacher in class by getting involved in the various processes of science, such as calibrating, measuring and designing experiments using improvised equipment, will be actively involved in the learning process perhaps without their own knowledge (Hodson 1993: 118). They will understand the subject matter well, and at the same time remain motivated to learn more of the subject. To encourage student-centred voluntary learning in the classroom and not simply teaching which is teacher-centred, it is essential for the teacher to create a teaching situation in which the students have the opportunity to react dynamically and learn actively. To encourage this, students must be allowed to ask questions, conduct experiments, make observations, draw conclusions, and solve problems on their own (Dreckmeyr 1994: 33). Teachers should plan their lessons ahead of time to provide such opportunities wherever possible. They should not only get students to be actively involved in the lesson, but also to get them to be motivated to learn. However, as warned by Dreckmeyr (1994: 33-34), planning should be done by the teacher and the students should not be allowed to take the entire responsibility to decide the course of events by themselves. Asking thought-provoking and challenging questions, stimulating their thinking process to an extent that students start asking probing questions on their own to get more information in the subject matter that is being taught, group interactions like quizzes and debates in class, educational tours to places of interest to give the students first-hand knowledge of the things that they have studied in class, are important ways of stimulating the active participation of students in a lesson. Active and enthusiastic participation in such activities also shows that these students are motivated to learn the subject and benefit by such learning. By so doing, students develop their own knowledge of science that makes sense to them, and the subject is learnt with understanding and meaning.

3.2.8.3 PRINCIPLE OF INDIVIDUALIZATION

Teachers need to accept the fact that a class consists of individuals who are different and that a class never consists of a homogeneous group of individuals. It is such individual differences among students in a class that cause difficulties and problems to a new teacher. Differences among students could be in respect of their physical, psychological or mental abilities. The principle of individualisation is based on this fact (Dreckmeyr 1994: 34).

While preparing his lesson, a teacher usually considers the abilities of the students in the class. The lesson is so designed that it caters for the needs of the average student group, that is the majority in class. The class is also bound to have some bright and intelligent students who are above average and some others who are below average. A teacher, while planning his lesson, must not only plan to meet the needs of most of students in class; parts of the lesson must also meet the demand of the few bright students and some components should cater for the needs of the below-average students as well. By such planning, a teacher can help to maintain the curiosity and interest of all the students in the class. This will encourage the bright students to progress further rapidly without getting frustrated by the limited learning offered to the majority in class; encourage the average student to try to catch up with the bright lot who are ahead; encourage the below-average to continue to work on those things that they can accomplish and not get frustrated by work that is beyond their comprehension. This will help them to progress further, and thus encourage positive attitudes towards the learning of the subject in class.

If the school has a laboratory and science equipment, then it is essential that teachers encourage students to get involved in doing science. In such a situation, different students will work at their own pace depending on their motivation, ability and interest. If science equipment is not available, by using improvisation, a teacher can achieve the same kind of effective learning of science as when there was an equipped laboratory. By using improvisation, students are more motivated as they have to do several things by themselves and in so doing, they have a chance to understand many other aspects of science as well. For example, looking for aluminium for an experiment at home, a student will learn to identify various metals from their appearance, texture, hardness, and so on, and know that the foils used in the kitchen for cooking are made of aluminium. Such challenge will stimulate students at all levels towards learning science through the process approach, and it shows the relevance of science to our daily life.

Whenever students are involved in doing experiments, we use student-centred method as the student is the one who is actively involved in learning. In such a situation, student interest is high and therefore students get motivated to learn. A lively and well-informed teacher who can make the lesson meaningful to the students, relate it to other subjects, the society and the environment, and show its usefulness to the students does not only make the lesson interesting; he also helps the students in active learning of the subject. A teacher will be able to do this by keeping in mind the individual differences and various needs and interests of the students. Improvisation of equipment and apparatus in the teaching of physical science helps the students towards realising the value of science and its contribution to society. Depending on the ability, level of maturity and motivation of the students, they could be encouraged to improvise apparatus and equipment in learning science. It should be borne in mind that factors like interests, abilities and exposure will play a great role in their ability to improvise equipment and apparatus in physical science.

Dreckmeyr (1994: 35) makes a distinction between individual teaching, like a lesson in music to a student, and individualised teaching, as in a class where the teacher designs the lesson in a way that accommodates the whole range of pupils and their different learning needs:

> Although the possibilities for individual work in physical science are unlimited, their successful application will depend on the teacher. Keen perception and foresight to urge the intelligent pupil to productive and original thought as well as the forbearance and wisdom with which to answer the questions of the average pupil in such a way that he does not become discouraged, are attributes for which the teacher should strive if he is interested in applying the principle of individualisation (Dreckmeyr 1994: 35).

3.2.8.4 PRINCIPLE OF SOCIALIZATION

Man is a social being. The school is a miniature society. Education is aimed at making a person fit in society harmoniously as a citizen useful to himself and to the society in which he lives. Though individuals are unique, they cannot exist in isolation. The development of their innate potential is the result of their interaction with others in the society. As a truly social being, man is dependent on his fellow beings (Dreckmeyr 1994:

35).

In teaching, a teacher has to select ways and means of encouraging socialisation of the students in the classroom. This is how favourable social relationships are developed and nurtured by students as a prerequisite to becoming useful citizens of the country. In the teaching of science, it is through group work that students have opportunities to participate in the learning activities. The teacher functions as a facilitator by guiding his students to work towards common objectives in groups. The advantage of socialization activities is that students influence each other and learn from each other (Dreckmeyr 1994: 36).

When improvisation is used as a strategy for teaching science, there are several opportunities for student-teachers to socialise, not only among themselves and with the teacher, but also with the people in the community from whom much help may be obtained to accomplish successful improvisation of apparatus and experiments. This is a good opportunity for them to realise the useful role members of the society play in a social situation. Normally projects undertaken for improvisation are done by small student teams. The members of each team have to socialise: they elect a leader, learn to obey the leader and the decisions of the group, work in harmony with others in the group, respect the work of the others and try and keep up to the level of achievement of others. There is a sense of cooperation and competition among members of the group. They further learn to be disciplined because they may have to complete their allotted part of the task within the given time. This develops a sense of responsibility as well. In the physical science classroom and the laboratory, a teacher can create several opportunities for socialisation, especially through group work. Groups may carry out experiments and process results; group leaders may control and look after the apparatus. During such activities sound competition between class members takes place and this is bound to keep the pupils motivated to do their best (Dreckmeyr 1994: 36).

3.2.8.5 PRINCIPLE OF PLANNING

The need for planning in education has already been emphasised in our discussion. The planning should begin with the lesson plan for each lesson. It should include lesson objectives, learning content, teaching strategies and aids, and the assessment of students' performance. In the case of physical science teachers, the planning will normally involve much more work. There is the need for such teachers to plan for individual and group experiments and demonstrations; ordering, maintenance and storage of equipment and chemicals; laboratory activities with regard to steps for safety; improvisation of apparatus and experiments; and the maintaining of a balance between theoretical and practical work in their classroom teaching (Dreckmeyr 1994: 36).

Planning is very important for any improvisation as many materials and chemicals for improvisation have to be obtained from outside the classroom. It is essential for a teacher to plan ahead of time. This allows sufficient time to obtain such materials from outside sources so that it will be possible to introduce the relevant process while teaching science in class.

3.2.9 IMPROVISATION AND SOME OTHER TEACHING STRATEGIES

A good teacher employs several teaching strategies for effective student learning. This brings in variety in teaching, motivates student learning and avoids monotony in the lesson. Judicious selection of methods to suit the lesson will decide the success of teaching. There is no magic formula for selecting a teaching strategy. Individual talent and ability of the teacher play a very important role in ensuring success of student learning. However, experience is always important in the choice and use of any method or strategy. The teacher's experience, combined with the knowledge of various strategies of teaching and the inner motivation for excellence, and a constant striving desire to improve his teaching strategies make any average teacher an outstanding one. It is in the interest of any teacher to work towards constant professional growth and excellence in teaching. This is amply rewarded, if not by the authorities in monetary terms, at least by the personal job satisfaction and the respect and status accorded him by his peers and students. This is worth aiming at, and it is not something that comes easily to a teacher who does not strive consistently to attain excellence.

The need for improvisation arises out of a need and necessity in the teaching of science in schools with limited facilities for practical work. However, improvisation has its own strengths and advantages. It could also be used in any classroom situation to make science lessons meaningful to the students, and bring about motivation and interest in the subject. Sometimes, it may be necessary to combine improvisation with other strategies for the effective teaching of science in class. Improvisation could be used with other strategies like projects, problem solving, self activity, small group activity, investigation, independent activity, demonstration, question and answer, discussion, and debate. All these strategies, depending on the particular circumstances, can either form part and parcel of improvisation or they can be successfully included when improvisation is used as a strategy in teaching science.

Projects can be used in improvisation when the teacher initially gives the students the basic idea of the equipment to be made or experiment to be conducted. This could take the form of class discussion or a problem-solving session to decide the project, the steps that have to be taken for doing the project and the pros and cons of the steps that are being planned. Problem solving by discussions could either be by self activity, where one student is involved in the project, or it could be in a small group activity where two or more students jointly accomplish the project. Such joint effort, teach them cooperation, obedience to the leader, a sence of responsibility to do the assigned portion of the work well, working with confidence, and accommodating views of others in a social situation. If the students need assistance, the teacher should suggest ways of getting the necessary help either from within or outside the school. In so doing, the students will embark on independent activity. They have to do certain assigned parts of the work by themselves, and also learn to carry out investigations to test if what they have made is functional or not. They also need to interact with the teacher and with their peers, ask questions and perhaps give answers and engage in debates if something does not work the way they thought it would work. Having done their home work and learnt facts and concepts, they could even arrange a suitable class debate on a controversial topic to give the whole class an idea of the problems they have been working on. All these activities involve the students themselves, and so the approach becomes student-centred. The students experience democracy in action in class as they are required to make several decisions based on various points of view. They learn responsibility and can discipline themselves. They become knowledgeable in the subject matter and learn other important lessons that are only indirectly related to what the syllabus might have originally intended. Their learning becomes wide and deep and it is done with motivation as they teach themselves. It is also a method that is satisfying to the students as they feel a sense of accomplishment on completing their project on improvisation. The teacher has to be a companion, a guide, a resource person, a manager, a leader, a friend, one who is sympathetic and understanding, knowledgeable in his subject matter, and one who can reach the right resources when needed to find out further information on the subject. Such a teacher is creative and is constantly aiming to reach great heights in stimulating student thinking and reasoning. It should be the aim of all science teachers to reach such a goal.

Moving away from the process/product paradigm accepted as a teaching method for science, researchers have come up with a very different view of learning. This view is important, for teachers use various strategies in teaching science. According to constructivists, students must construct their learning for themselves. In the viw of Watts & Pope (1989: 327), quoting Mahoney (1988), "constructivism refers to a family of theories that share the assertion that human knowledge and experience entails the (pro) active participation of the individual." From a constructivist perspective, the approach would be less normative, and more student-centred. The task of the physics teacher then becomes that of

* encouraging the pupil to share and eventually own the purpose for the lessons or activity;
* developing learning experiences that allow pupils to take responsibility for the design, process and outcome of the investigation;
* valuing pupils' hypotheses and conclusions and generating discussion of the scientific description of what has been taking place in the activity (Watts & Pope 1989: 329).

These specific objectives could all be achieved by the use of improvisation in teaching physical science.

Donmoyer, White & Klapper (1991: 14) however points out that "...laboratory experiences do not in and of themselves guarantee constructivist teaching. Rather, teachers must have both the freedom to work somewhat improvisonally with students in the lab and the skill to make this improvisational work educative." In order to achieve this objective, more group work and opportunity for discussions will be needed. To bring about this, better dialogue between the teacher and the pupil that will make the lesson more enjoyable to the students should be encouraged. The use of improvisation in teaching physical science has great appeal, for it can be used to cause this constant dialogue and interaction needed for the constructivist method of teaching by providing opportunities for making use of the so-called laboratory experiences even without science laboratories and equipment.

Problem-based learning is also a part of improvisation in the teaching of physical science. Teachers wishing to use problem-based learning strategy could benefit by the following guidelines suggested by West (1992: 55):

1. The objective for the lesson must be clearly stated and must be kept in mind by the teacher.
2. The problem should be short and to the point. Too much information would introduce materials that may move too far from the learning

objectives.

3. The 'opening brainstorming' session allows students to introduce anything related to the problem that interest them.
4. Although the students should be given a choice of the issues they wish to follow up, the teacher should ensure that all the learning objectives are included.
5. Ensure that the resource material that you make available to the students contains the information they require. Always try to have some extra resource material, mainly reference books on hand.
6. Encourage the students to talk freely to each other and to examine critically any data or statement presented.
7. Get with other subject teacher to try to integrate science and other subjects.
8. Students may need help in searching for information.

The process of problem-based learning was summarised by West (1992: 48-49) in two phases as follows:

PHASE 1

1. Problem presentation.
2. Identifying the issues.
3. Framing learning objectives/questions arising from issues.
4. Listing of priorities (objectives/questions).
5. Determining work schedule.

PHASE 2

6. Students work on issues.
7. Students' presentations and discussion of issues.
8. Summary of what has been learnt.
9. Evaluation of students' and tutor's performance.

Problem-based education is rooted in the belief that

> every time we have the opportunity to use the information learned when trying to solve the problems in our day-to-day activities, the information becomes more firmly embedded in our learning system. ...We not only learn by problems, we apply what we learn in the context of problems. Therefore in the teaching-learning situation in the classroom, it seems logical to conclude that more use should be made of problems. ...the current information explosion has made it undeniably clear that it is impossible to teach a student the knowledge needed in order to be an effective citizen...even if this were possible ...the students' knowledge would become outdated (West 1992: 47-49).

It is important to gain information from our confrontations with problems instead of simply gathering information because

> ...the great wealth of information we possess in our memory banks has remained there as a consequence of having worked with problems we have been faced with in such life situations as school, work, social situations and our hobbies (West (1992: 47) quoting Barrows & Tamblyn (1980)).

This method is especially suitable when improvisation is used for teaching science. It is also useful in trying to integrate other subjects with science, thus making science meaningful and a useful subject. It also helps the teacher to reach his objectives and learning by problems or hurdles we encounter in real life situations. Such learning remains for a long time as part of our understanding. It also gives the satisfaction that encourages one to face other problems with confidence in life. This method therefore encourages a student to succeed in doing improvisations and make it a useful learning process. In turn, it enables the student face the real world that is full of problems to be faced and solved by every individual.

3.3 TEACHER TRAINING

Teachers' influence on student learning is profound. However, "far too many science teachers are teaching as they were taught in their own high school and college science classes" (Yager 1991: 91). To break away from this outdated traditional method of teaching and to bring about an improvement in teaching, several countries are devoting a lot of money and effort to training their science teachers. This is because the success of any science education program depends on the teacher. Mordi (1992: 253), quoting Jegade (1989), says that "the pivot of any science education program is the teacher." He adds that "the success of the program depends on how positively attuned the teacher is to its implementation." He speaks of many instructional behaviours as listed by Yager (1986) which are desirable for "a science programme approaching excellence." These are certainly worth noting and following if one wants to become an outstandingly 'good' science teacher. Most of the objectives listed below could be achieved by improvisation in teaching science. The list of objectives is as follows:

1. Teachers value enquiry, encourage such orientation, and possess such personal skills;
2. Classroom use science objects and events where students focus on investigation;
3. Curricula and unit instruction give attention to science processes, the nature of enquiry, the necessary attitudes and values;
4. Teachers act as role models in debating issues, admitting errors, examining values, and confronting their own ignorance;
5. Instruction focuses on exploration rather than coverage (Mordi 1992: 253).

According to Mordi (1992: 253), though much research has been done on the main characteristics of an effective teacher, very little has been done to assess students' own perception of the ideal teacher. This is something that teachers ought to know, because it is the students who are being educated. Feedback from them as to their perception of an effective teacher will be a very valuable prescriptive model in the teacher-training programme.

The process of teacher-student interaction which was referred to by Tamir (1983) as "actual classroom transaction," which includes, among other interactions, curriculum evaluation and research into teaching, have been researched by some scholars. An opinion poll conducted by Thollairrathil (1973) and Teibo (1975), according to Mordi (1992: 253), revealed that teachers favoured the "lecture method." No such "actual classroom transaction" studies seem to have been conducted in Venda. But based on personal observations of teachers, teacher-trainees and the responses of both students and student-teachers to formal and informal questions, obviously the lecture or telling method of teaching has been extensively used in schools in Venda, too, and it is still the most commonly used method of teaching in schools in Venda.

3.3.1 PRESET AND INSET

Teacher-training at both the pre-service and the in-service stages is essential for giving the teachers the necessary background knowledge and experience to help them improve the quality of instruction in science. This will also help them to change their traditional methods of teaching from telling or lecturing to active student participation in learning methods with an emphasis on science processes and skills in keeping with the modern trends of science education. Thus "pre-service and in-service teachers can learn appropriate subject matter and methods of teaching" (Walberg 1991: 46). There is another aspect of science education that has to be addressed:

> Teachers should be made to realise that the nature of the science taught does affect students' attitudes towards science. Teachers should be provided with appropriate

> in-service education that will enable them to portray science as fun, exciting and interesting while fostering curiosity. Also prospective teachers need to experience science more as enquiry and less as didactic, passive lectures followed by confirmatory laboratories (Mordi 1992: 257-258).

Teacher-training, both at the pre-service and the in-service levels, according to the National Council of Teachers of Mathematics (NCTM 1989), as quoted by Tobias (1992:43), should be such that

> Teachers must be taught in a manner similar to how they are to teach - by exploring, conjecturing, communicating, reasoning, and so forth....All teachers must understand both the historical development and current applications of mathematics.

What is true of mathematics is also applicable to science. It is unfortunate that in several teacher-training institutions in Venda, the teacher-training programme is still followed more through the method of a theoretical telling of facts. Therefore, teacher-trainees who follow the program also resort to rote-learning to pass their examinations, and when they become teachers, resort to the same telling method of teaching their pupils. This is the vicious cycle that is being perpetuated, preventing students from thinking, applying and operating at higher cognitive levels on their own, and this results in the perpetuation of mediocrity in science education. These comments are based on personal observations and on the available information regarding staffing in the Department of Education, Venda (Figure 1.3). To improve the quality of science teachers in colleges, retraining followed by in-service training of college lecturers is essential in the interest of improving science education in Venda in keeping with the Reconstruction and Development Programme in the new South Africa. Recently, the task team on Science, Technology and Mathematics (with Kahn as the coordinator), in its recommendations for breaking the cycle of mediocrity in science and mathematics education, has identified the need for intensive curriculum and staff development in the colleges and thus providing new roles among the universities, technikons and the colleges themselves. "In addition, the need for staff development in the colleges may be addressed through new MEd programmes at Universities" (Centre for Education Policy Development 1994: 5).

Teachers need help to be informed of the various effective methods of teaching. Knowing different methods will not necessarily result in teachers using them, unless they are given enough confidence through practice and experience in the use of these methods. The method a teacher uses in class is entirely his own choice. However, it is essential for the teacher to be aware of the recent trends and developments in modern teaching methods. There is also a tendency for teachers to revert to the old method that they are usually familiar with, having tried 'under pressure' new methods for short periods. To facilitate their continued use of new and better methods of teaching, in-service training of teachers becomes useful from time to time. Even trained teachers who are in service need regular in-service training that will help them to continue to use new and better methods in their classroom teaching. The one-year University Education Diploma (UED) course, from the researcher's experience, is insufficient to equip the graduate teacher-trainees with the necessary knowledge in their teaching subjects, especially in physical science. There is a need for these trainees to be trained further in physical science if they are to bring in any marked change in the teaching of the subject in schools in Venda. This could be done either by giving an extended period of training in physical science to such trainees or by providing further in-service training while they are employed as teachers in the field. Retraining and continued in-service training could also be very essential for the existing science teachers in schools if any marked improvements in the teaching of physical science in the schools in Venda are to be achieved. If in-service courses are conducted regularly, it also provides the teachers with common meeting grounds to share their teaching experiences with others who are in the same profession.

> Teachers must continue to develop a wide range of teaching strategies to cater for the diversity of personal experience and differentiation of individual attainment to be found in any class. Since one single strategy will not work for all occasions,

> teachers must be able to draw on many - and constantly move between, modify, add to and refine a comprehensive 'tool box' of methods. Practical explorations, role-play, small group discussions, problem solving, debates, Young Engineers Clubs, mime, CREST (Creativity in Science and Technology) projects, industrial materials, video-making, egg races, field work, creative writing, design and make activities, drama...are some of the many possibilities which exist in physics as in any other part of the curriculum (Watts & Pope 1989: 330).

The EXPO for young scientists introduced in 1992 to Venda schools is an excellent means of motivating student involvement in project work relating to 'doing' science outside the school curriculum on a purely voluntary basis. It should also indirectly induce science teachers to be innovative and to do their own projects or at least help the students who are involved in their own project work to complete their projects successfully.

3.3.2 SCIENCE MISCONCEPTIONS (TEACHERS AND TEACHER-TRAINEES)

Many teachers and teacher-trainees who are supposed to 'know' science and show an understanding of science do not seem to have proper understanding of the subject. On the contrary, they have occasionally shown their misunderstanding of basic scientific principles and concepts.

Teacher-trainees following the postgraduate University Education Diploma (UED) course at the University of Venda had to do certain science projects on their own using simple material available at home and in their environment. This was aimed at giving them a hands-on experience in making and using simple equipment to equip them to teach science in schools with understanding and insight even where a school did not have a science laboratory or science equipment. Such teacher-trainees came out with several wrong ideas concerning materials and chemicals that are in daily use in our homes. For example, they were not sure of the properties, differences and similarities between steel and iron, their use in daily life and the common examples of materials made of steel and iron. This came up when they had to select suitable materials to construct a simple electromagnet and a permanent magnet.

These trainees were also given simple general topics and reading material in science to prepare mini-lessons that they were supposed to present in class to enable the other trainees to comment on the success of the lesson presented in class. This was a way of learning to write lesson plans and start teaching in front of a class before the actual teaching practice. A teacher-trainee who was supposed to present a lesson on steel had difficulties in preparing the lesson, because he was not sure of the similarities and differences between steel and iron. Similarly there were many other problems brought to light in such activities, including the following:

* Tin cans were considered to have been made of the metal tin.
* Chlorine gas when dissolved in water, appears greenish yellow in colour.
* Tap water at home becomes milky at times because of the chlorination of water.
* A balloon filled with air will go up in air.
* Aluminium as a metal is only available in the laboratories.
* An electroscope can only function if it has a gold leaf.
* Magnets are not affected by dropping them.
* Attraction shown by a compass needle is proof of a magnet.
* Witchcraft enables one to cause lightning to strike and kill people.

From among the teachers who attended a one-day in-service workshop in science recently (25 March 1994), at least one teacher came out with the explanation that if two very different masses are dropped from the same height, the heavier mass will touch the ground ahead of the lighter mass. Such statements were also made by some teacher-trainees following the post-graduate diploma course in the previous years.

Such teachers and teacher-trainees in the UED course were not quite sure of the factors that influence a pendulum and its period of oscillation. The concept of period and frequency was not clear to them. Most of them could state the relationship between period and frequency and could define these terms. However, they did not have the concept of a period and a frequency. Therefore, they could not explain what these terms meant in their own words. This lack of the concepts of period and frequency was the cause of the problems they experienced when these terms were used for waves and vibrations. The teachers found it difficult to go from the first principles or from the understanding of a period to find out the frequency, and vice versa, of an oscillating pendulum. The problem which secondary school students following physical science courses experience concerning proportional reasoning, studied by Selvaratnam (1991: 8) in Bophuthatswana, could have resulted from the problem teachers have in understanding proportional reasoning themselves. This is because the teachers do not understand the basic concepts both in science and in mathematics. Such shortcomings are the cause of the teachers using the 'security' of the textbook and the telling method in teaching science. Along with this, the teachers use their authority to prevent students from asking questions so that they can avoid any problems regarding content that they are not familiar with. This is one reason why teachers continue to use the traditional method of teaching science, even today. Such teaching naturally leads to students memorizing facts of science without understanding them, thus making science a difficult subject to study. The report by the Task Team on Science, Technology and Mathematics states that "the rate of attainment of matriculation exemption with physical science and mathematics at higher grade among students of the majority community is ONE SIXTIETH that for students of the minority" (Centre for Education Policy Development 1994: 2).

As Yager (1991: 97) appropriately remarked, "future teachers must themselves have the experience in using science concepts and processes in real world context. They must use science in taking actions." Teachers have been teaching Newton's Law of Universal Gravitation. They have read in their science textbooks and even taught in class that a feather and a steel ball when allowed to fall freely in a glass tube without air (in vacuum) will fall together to the bottom at the same moment. But how many have experienced this or done this experiment or seen it really happen? The usual experience is that light objects float in air and take a long time to reach the ground as compared to heavy objects that crash quickly on to the ground when dropped from a height. This concept that teachers originally have must be replaced with the changed concept according to the said Law of Universal Gravitation. To cause this change of basic concept, the teachers should themselves have experienced this to alter their existing (mis)conception so that the new concept becomes part of their own understanding. If only teachers have the chance to see and do by themselves the following simple experiment, they will not have such fundamental misunderstanding concerning Newton's Law of Universal Gravitation:

> Drop a coin (held horizontally) and a tiny piece of paper held side by side together at the same moment. Ask students to observe which one touches the table (or the floor as the case may be) first. Preferably repeat it (several times if necessary). (Sometimes, the piece of paper, unlike the coin, will not fall when it is released as it may stick to the fingers. What can be done to prevent the paper sticking to your finger and by that influencing your result adversely? Perhaps, applying some face powder to your fingers handling the paper will solve this problem.) Next, place the same piece of paper (Why not a different piece of paper?) on top of the coin (held horizontally) and repeat the experiment. What do you notice now regarding the falling of the two objects? Do you get the same result on repeating it? Why is your present observation different from the previous one? Ask the students different questions along these lines to make them THINK of the reason for the difference in behaviour. From such stimulating questions you can lead to the idea of Newton's Law of Universal Gravitation. This experiment is so simple and yet makes students understand the difficult concept quite clearly. They can themselves repeat this simple experiment. In doing this experiment, there is no need for a

> vacuum pump and other sophisticated equipment that are normally needed to illustrate this concept in a laboratory.

A simple but effective experiment of this kind, improvised from simple equipment (even on the spur of the moment), will not only help the students to think of many things and understand the law, but will also make it quite clear to the teacher what he is trying to teach: it will remove his previously held misunderstanding of what Newton proposed long ago. Such experience will also enable teachers to link their science to life and apply correctly what they have understood to any new situation in life.

Teachers have not developed the right scientific attitudes and are not made to think and 'see' for themselves what is around them in their immediate environment. They have not used such basic scientific principles of enquiry as objectivity, doing experiment under controlled conditions and eliminating all variables except the one in question. They have not used the opportunity to raise doubts and clarify them through discussions with others. As Fensham and Northfield (1993: 75) remarked,

> ...many adults including science teachers, hold many conceptions found in their students, as well as others we could call 'Teachers' Science', but also that learning is conceptual change rather than conceptual reception is quite fundamentally different from the view of science teaching most science teachers hold. Conceptual change, be it one's notion of force or chemical reaction, or of what teaching science involves, is difficult to bring about. It occurs only slowly and after consistent exposure to the ideas others hold and to experiences that challenge the adequacy of one's current ideas.

This lack of proper understanding results in the teachers teaching science content by the textbook method that encourages students to learn science by rote.

When teachers are exposed to the environment in their study of the content in science, they themselves start learning science for the first time meaningfully and relating the science they learn to their environment. They start to 'see' that there are foils and vessels in the kitchen made of aluminium. Teachers start to examine the differences between an iron nail and a steel nail. They may even go further to find out if Coke cans are made of aluminium or iron and start asking questions about why there are stainless steel vessels and vanadium and chromium steel tools and what their compositions and properties are. If teachers can be made to think and ask such probing questions on their own, then they are starting to function as scientists. They become perceptive and receptive to their environment and are keen to learn as scientists do. Then they would have argued that as air has mass, and a balloon also has its own mass, a balloon filled with air cannot be lighter than air and therefore cannot rise on its own and float in air. By trying to improvise simple experiments in learning science by doing, teachers learn many fine details that we all assume that we know.

This valuable micro-dimensional learning experience is difficult to anticipate and teach, unless one learns by doing and making mistakes and correcting them so that their experiments eventually work. An example will illustrate this point clearly:

> A teacher-trainee presenting a project in class on magnetism used the end of the magnet on the object to be magnetised, by rubbing it in a stirring manner. She was, as a result, not in a position to magnetise the object satisfactorily. However, to test if this is now magnetised, she used a magnetic compass. This compass was hung vertically instead of horizontally, perhaps because it had a convenient ring on one end. This was done so that the rest of the class could see the compass needle clearly. But what the 'teacher' was not aware of was that the compass in this vertical rotating position would not respond. Besides, the object was not even magnetised. The other teacher-trainees ('students') who were watching this experiment never pointed this out to the 'teacher'. They were in full agreement with their 'teacher' when she said that there was a movement of the compass needle. The slight movement was perhaps because of the object being attracted by the magnet in the compass.

The 'students' here agreed with the teacher as their culture is to respect a teacher or any person in authority. They did not think critically and were not bold enough to challenge even their colleague who was for that time being a teacher. It was also surprising that no one mentioned that a compass will not work in this vertical position. No one even thought that when two objects attract each other, both need not be magnets. If one pointer of the compass repelled, then it could have been a positive proof of that object being a magnet. When these were later discussed, they were somewhat surprised. But this exposure was a good learning experience for all. The resaearcher would not have imagined that graduate teacher-trainees would show such shortcomings. The learning of finer points because of this exposure was very valuable to all, including the trainees who perhaps will start looking at things critically from now on and not simply accept the word of the teacher. Hopefully they will also encourage their students to be critical when they go out soon as science teachers.

3.3.3 IMPROVISATION IN TEACHER-TRAINING

Improvisation of simple equipment using material available from the immediate environment provides a great learning experience for teachers. They see science as a subject related to the environment. They see that scientific knowledge is always useful in life. Realisation of this by the teachers is important for them to teach science with some understanding. The process of improvisation also gives them first-hand, hands-on experience of doing and seeing science work and so they form the right concepts and correct their misconceptions with which they have grown. This change in teachers is important if they are to make any useful change in the teaching of science. Teachers, we saw, are always the agents of change and if the change is to the advantage of the students, then one way of achieving it in an inexpensive and useful way is by resorting to doing science using improvised equipment.

Doing experiments using improvisation will provide better understanding of science to the teacher. It will provide him with the application of science to daily life and to the environment. It will help the teacher to clarify his ideas about science by doing and thus help him to form the right concepts and provide him with the much-wanted experience to do and manipulate objects that form an important but neglected psychomotor aspect of science education. By taking such an action, science will become a meaningful subject, and the students too could do some improvisations on their own. By so doing, the students will not only show their initiative and talent in doing science, but also reveal their hidden abilities, thus paving the way to becoming useful and productive educated people in the society.

In trying out experiments on their own, teachers also learn of the available materials in the environment and the resource persons in the society to whom they could go for help to make the experiments work. Science teachers should be aware of this and acknowledge the fact that they are always learning. They should also know that they could seek help from others in the community who are knowledgeable in their own specialised field of work. This is another aspect of methodology: to seek the right source for help when the need arises. This helps them function properly as science teachers.

The Committee on the Teaching of Science (CTS) was set up in 1968 by 20 international Council of Scientific Unions and 71 national members to coordinate interdisciplinary science teaching activities. It has held international conferences on integrated science and the relevance of science to society. Some topics discussed in the workshops conducted by CTS include the production of locally-produced low-cost equipment, science education reform and technician training. Following a conference on topics identified as the most important for development, sponsored by UNESCO and other agencies and attended by 60 countries, many of them developing countries, a series of nine books on the following topics has been produced:

1. Science and Technology Education and Future Human Needs.

2. Ethics and Social Responsibility in Science Education.
3. Education, Industry and Technology.
4. Mineral Resources in Science Education.
5. Education and Health.
6. Food, Agriculture and Education.
7. Energy Resources in Science Education.
8. The Environment and Science and Technology Education.
9. Science Education and Information Transfer (Walberg 1991: 61-62).

These books are of interest to us as they provide valuable descriptions of how educators in low-income countries use indigenous materials and methods to build suitable science equipment to suit their science curricula that are relevant to their local conditions (Walberg 1991: 62). In addition, the UNESCO Source Book for Science Teachers (UNESCO 1960) is an excellent book that has a large collection of experiments that could be conducted in class using totally improvised equipment.

Teacher-trainees doing physical science as one method subject at the University of Venda are expected to work on projects that are randomly allocated to them during their training period. Having completed the project assigned to them, they have to present their project to their peers in class. This method of allowing them to work on science projects on their own and presenting them to their peers in class has several advantages. It was indeed a very valuable learning experience to them. Usually they are not supplied with equipment and they are expected to complete the projects using, as much as possible, improvised apparatus. Those who seek help are given the necessary guidance to complete or perfect their project. Some advantages of this method are:

1. They learn to work on their own and make their own decisions regarding their projects.
2. They learn to seek help whenever needed at the right time.

3. They learn to see and know the materials that are available in their environment.

4. They come to know of the resource people in the society who could be contacted for help in specialised fields of science.

5. In producing simple equipments and conducting simple experiments, they learn many finer points that cannot be taught or anticipated by the lecturer.

6. Having done the experiment with the equipment, they learn to 'fine tune' it and improve its efficiency by trying to modify it, thus learning finer details in constructing and improving the equipment and experiments.

7. They learn to present an equipment/apparatus to the 'students', thus gaining hands-on experience in doing and teaching science in front of 'students'.

8. They learn to take control of the class and see that students are suitably arranged to help everyone see the demonstration well and get as many 'students' as possible to be involved in the lesson.

9. They learn to ask the kind of relevant questions while demonstrating to make the demonstration a challenging and valuable learning experience.

10. The 'students' learn role-playing, which helps them to think the way real students think and react in class - a very valuable learning experience indeed. This helps them to know the problems in understanding, visualizing and extrapolating experiments and ideas which students may experience in a classroom situation.

11. The 'teacher' learns to respond to the questions and doubts raised by the 'students'. This can only become better with experience, and exposure, reflective thinking and analysis of the teaching process that happens during this exercise.

12. The 'students' have a chance to criticize their 'teacher', comment on his good points, point out his shortcomings with the sole aim of helping him overcome these problems before he goes out in front of real students in

class. Learning is much better if shortcomings or errors are identified because identifying the errors or shortcomings helps a person to correct them so that he could avoid them in future.

13. The good points noted by the peers become an encouragement to the 'teacher' and at the same time forms examples of qualities that others (including the lecturer) can emulate.

14. The whole process, not being a real classroom teaching situation, helps the teacher-trainees to be somewhat more relaxed in the 'class' and thus enjoy the experience this simulated teaching and the learning process offers to them.

15. The experience they gain through this exposure becomes very useful when they are in a real teaching situation in a classroom. It also helps them to relax and use all that they have learnt in a 'staged' situation when they are in front of the real class.

16. Through this exposure, all teacher-trainees learn many facts regarding improvisation for several experiments within a comparatively short time either by doing in front of the class by themselves or by actively participating as 'students' in the class during their role play.

17. The lecturer plays an observer role, can summarise his observations for improvement and can evaluate student progress and performance, while at the same time getting better insight regarding their learning activities and their misunderstandings.

18. Learning to teach science meaningfully takes place through this method, not by the lecturer impressing and imposing on the student-teachers the value of this method, but by the student-teachers themselves experiencing the process by getting involved in teaching and doing the projects and learning by themselves.

In responding to the end of the year course evaluation questionnaire, teacher-trainees who followed this course remarked that this activity should be started early in the year and more time should be spent to give them this kind of hands-on experience in improvising and in classroom teaching. They also suggested that such opportunities for presenting projects should be made available every term during the year. They were all very enthusiastic about this approach and remarked that they not only enjoyed these presentations, but were also able to learn quite a lot in the process. The trainees agreed that it was the most enjoyable component of this course and many were keen to use improvisations in their classrooms when they were out as fully-fledged science teachers in schools. However, when this plan was first announced at the beginning of the year, the teacher-trainees were not at all pleased with this method. They instead insisted on the researcher providing them with equipment to work with in the laboratory. However, as they were almost forced to do the projects on their own, they did much of the searching for material and came for assistance when they failed to get the necessary material. This need to do the searching and make things on their own made them come out with all possible excuses to have their presentations of projects postponed as far as possible. The value of this exercise was realised only towards the end of the year when it was too late for them to continue with this kind of work any further. From such experiences, it is clear that the judicious use of improvisation and the presentation of project work is quite valuable in the training of science teachers. It has tremendous advantages in bringing about remarkable changes in the teacher-trainees that will help them become self-motivated teachers who could inspire their class and teach science in such a manner that the students experience the joy of learning science and as a result attain all the five domains of science education as proposed by McCormack & Yager (1989: 47).

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CHAPTER 4

STUDENT-TEACHER RESPONSE TO IMPROVISATION

4.1 INTRODUCTION

'Student-teachers' in this chapter refers to the teacher-trainees following a one-year postgraduate University Education Diploma (UED) course at the University of Venda. There were fifteen student-teachers offering physical science in 1994. Improvised apparatuses such as do-it-at-home projects were given to these trainees who were following the UED course at the University of Venda from 1991. The numbers of trainees enrolled for this course has been varying from year to year as given in table 4.1.

YEAR	NUMBER
1990	06
1991	19
1992	15
1993	19
1994	15

TABLE 4.1. NUMBERS OF STUDENTS MAJORING IN PHYSICAL SCIENCE IN THE UED COURSE (1990 - 1994).

Each trainee usually offers two major teaching subjects, Educational Foundations, Professional Studies and few other optional subjects. Each major teaching subject is allotted four teaching periods per week. The diploma is a one-year full-time or a two-year part-time course. The physical science methodology content as given in the University of Venda (1994) Calendar is as follows:

PHYSICAL SCIENCE METHODOLOGY (PSM 470)

Assessment: Course work and one 3-hour examination.

1. The nature and structure of science.
2. Science in the school curriculum.
3. Instructional aims and objectives of science teaching.
4. Preparation of scheme of work and lesson planning.
5. Methods and techniques of using equipment.
6. Assessment and evaluation.
7. Laboratory management.

From among the senior secondary schools in Venda, where physical science is taught as a subject up to standard 10, there is at least one school that has a proper physical science laboratory equipped for practical work. Even here, it appears that the laboratory is not used regularly for individual or small group student practical work, but largely for teacher demonstrations. This school is the leading science school in Venda. Students are admitted to this school from other schools purely on merit from standard six onwards. This is a well-known school as it usually produces the best results in Venda. In 1994, the students with the best and the third best Department of Education and Training (DET) matric results in the whole of South Africa were from this school.

By contrast, most of the other schools offering physical science do not have equipment and/or facilities for practical work in their schools. Some schools have some equipment stacked away in a room or some cupboard. There are a few schools that have had science laboratories built, but they are for some reason not maintained and used as laboratories today and most of the equipment in these schools are missing. It was in 1993 that some selected schools were supplied with science kits, and some further forty schools were included in the Science Education Project (SEP) programme in Venda. Many schools do not even have a proper principal's office and/or a staff room for the teachers, let alone science laboratories with equipment for teaching science. Under such conditions, science teachers have to mostly work without any facilities for teaching science. Fully-equipped science laboratories cannot be expected to come up soon in the schools in Venda.

4.2 NEED FOR PROJECT PRESENTATION IN TEACHER EDUCATION

The training given at the colleges and the University in such aspects as the laboratory management and the methods and techniques of using equipment is basic and essential for science teacher-trainees. However, such training becomes theoretical to these teachers as over 90% of the teachers, after training, will be teaching in schools where there are no laboratories and equipment. Therfore they have no opportunity to apply what they learn in the course to real life situations in their schools. Such theoretical learning is what these teacher-trainees will also advocate when they obtain their diploma and assume duties as science teachers in schools. This could be another reason for science teachers continuing to teach science theoretically based on the textbooks rather than on varied cognitive and psychomotor skills that have relevance to real life situations.

Teacher-trainees who are usually science graduates (except a few who have to complete one or two outstanding degree courses) are the ones normally admitted to the UED course. It has been noticed by the researcher over the years that such graduate science teacher-trainees are deficient in certain important aspects of science. They are generally not quite sure of the fundamental concepts of physical science. They have not acquired the skills of applying their knowledge to science as a doing subject. They have learnt science using the content, rather than forming their own basic science concepts. As a result, these trainees show great proficiency when it comes to contents in science that need no application, critical interpretations and extrapolations, but only straightforward simple recall of mastered abstract science contents. When it comes to relating and applying their knowledge of even basic science concepts and scientific principles to daily life and/or technology to solve real problems encountered in life, their capability is very limited and the skills are inadequately developed. This shortcoming makes them teach science based on routine information from textbooks. The trainees do not encourage discovery learning or learning of science by doing, applying, extrapolating, developing general principles and forming their own basic science concepts and scientific skills. Thus, the science teacher-trainees do not know ways of applying their knowledge to any real situation they may be facing in life. It was such observations that led the researcher to introduce them to doing simple science projects during their course. By allowing them to do simple projects, it was assumed that the trainees could usefully apply science to other real life situations. This would in turn enable them to learn many facts that they would not have learnt, had they not done these projects. This would bring about meaning to the study of science at school.

In 1991, when doing project as part of the diploma course was introduced, the teacher-trainees were given the option of selecting for themselves any simple project on their own. The projects they finally presented were very elementary and do not merit mention here. This is because the teacher-trainees doing their post-graduate diploma course did not have the necessary initiatives to refer to the recommended books and resources, look for and collect interesting projects and discuss them fully before deciding on the selection of suitable projects to fulfil the requirements of the course. The lack of such initiatives among teacher-trainees, though they are at the post-graduate level, is a commonly-observed shortcoming. This goes along with their teacher-dominated textbook type of learning that they have been used to for a long time. Having thus experienced poor quality projects from the teacher-trainees that year, the researcher decided to supply the next year batch of teacher-trainees with a collection of projects with information for doing the projects using improvised material. Many suitable resource books are available for such projects, the outstanding one being the UNESCO Source Book for Science Teachers (UNESCO 1960). Having assembled the sets of experiments, the trainees were allotted the worksheets at the beginning of the year by the draw of lots that was fun to them. These sheets helped them to focus their attention on the given experiments and work on specific projects right from the beginning. Each sheet thus prepared comprised an assortment of experiments from different topics to give them variety and an ability to work on projects from various aspects of physical science.

The teacher-trainees were told that they would not only have to prepare the projects and make them work, but also present them to the rest of the group on stipulated dates. They were also told that these would be evaluated and the assessment would count towards their year mark. However, as it came closer to the time of the presentation of the projects, the teacher-trainees had several excuses for not being able to do all the projects on their sheets, and wanted the number of projects reduced. Negotiations resulted in their presenting two projects per person to the group that year. The presentation of these projects had such an impact on the teacher-trainees that they commented later that this was the best part of their training. They really enjoyed it and benefitted by it.

In 1993, similar arrangements were made with changes in the project groupings and the trainees were told to present three projects each. This was reduced to two during the presentation due to the lack of time. In their end-of-year course evaluation questionnaires, the trainees again unanimously agreed that this was the best learning experience for them. They suggested that such presentation of projects should be done every term instead of once towards the end of the year for it to serve a more useful purpose in this course.

The EXPO for young scientists was introduced in Venda in 1992 for the first time. Some schools and a college took part for the first time that year. Though students competed at the national level, no one got any placing that year. The EXPO Regional Committee was elected in 1993 and the researcher was elected as the Vice-Chairman of this committee. It was then that the researcher came to know that students from universities could also take part in this competition in certain areas, one being educational aids. Therefore, all the teacher-trainees doing physical science as a method subject were encouraged to produce educational aids using improvised equipment, based on the information supplied to them for their science projects. This resulted in the teacher-trainees working in groups of two on set projects, some doing poster presentations, others doing experiments in chemistry and yet others in physics, and so on. This activity led to much learning, understanding, team work and planning, which brought the hidden potentials of some trainees. This also showed that science projects, though they took much time for preparation, generated much interest and enthusiasm among the trainees. This resulted in the teacher-trainees teaching themselves. All their efforts did not go unnoticed when they exhibited their projects at the National EXPO competition in Pretoria. For the first time, Venda region received two silver medals that were carried away by two of the teacher-trainees who did a project on electromagnetism. The equipment for this project was fully improvised and assembled by the trainees. The winding wires for this project were obtained by the trainees from a shop in town dealing with rewinding of car motors and alternators. These materials were given to them free of charge by the owner of this shop because the trainees asked for them, explaining the reasons for asking. Such achievements gave all the teacher-trainees confidence and enthusiasm, and as science teachers in schools today, they will no doubt encourage their students, in turn, to also take part in such competitions. These teachers have the necessary experience to guide their students to do projects in science. They were also able to see the high quality of projects students submitted from all over Southern Africa when they visited the national EXPO competition at Pretoria. This exposure, courtesy of the FRD, must have given the trainees some idea of the amount of effort they should put in, if they have to develop science education in Venda to come up to standards that are comparable to those in the rest of South Africa.

In 1994, too, similar arrangements were made regarding projects and their presentations. The trainees were told that they should present at least three projects each. They could choose the ones they liked most from the list of projects supplied to each one of them. They were also told that their projects and their presentations would both be evaluated and would count towards their year mark. This motivated them to attach the necessary seriousness to their projects, refine and improve them and to present them properly during their presentation to their peers.

The trainees were instructed that they would work on these projects outside the normal teaching time. They were told that wherever possible they should try to obtain material for their projects from outside the laboratory using the resources from their environment. They are generally discouraged to use equipment from the laboratory, though they are told that the laboratory will be available for their use if they need it to do their projects.

Unfortunately, in 1994 the physical science methodology laboratory was undergoing renovation. As a result, the laboratory facilities or equipment were not available for the teacher-trainees for most of 1994, till about three weeks before they presented their projects. This factor, along with other disruptions experienced during the year, prevented them from taking part in the EXPO for young scientists competition in 1994.

The teacher-trainees are encouraged to seek help from their environment to obtain material for the projects and the technical know-how from resource personnel running different businesses or industries in their environment. This is done to make them know that there are further ways of obtaining information outside the classroom. This also gives them an opportunity to know the real application of science to the outside world. Through exposures of this kind, it is hoped that the teacher-trainees will realise the usefulness of science in our daily life. They also start to see the value of learning science that has application outside the classroom. In addition they learn to do experiments using materials from the environment. The absence of laboratories or equipment will not prevent the trainees from teaching science as a doing subject. Because they know the resources in their environment, they learn to seek help when necessary. They learn to do experiments with limited resources. It is hoped that teachers who realise the meaning of science will, in turn, teach science in such a way that it is made meaningful to their students. Such teachers should be able to teach science as a doing subject, even without laboratories and equipment. This is one important step in the right direction to make physical science an interesting and enjoyable school subject among students in Venda.

4.3 PROJECT PRESENTATION BY THE TEACHER-TRAINEES

The teacher-trainees not only prepared their own projects, but were also allowed to present their projects to the rest of their peer group in class. This was done under the watchful eye of the researcher who played an observer role most of the time. This gave the teacher-trainees an opportunity to teach in front of a class the science concepts used in the project they had been assigned, and they had themselves prepared and taught the concepts using improvised material, wherever possible.

As it is not a real classroom situation, the trainees were relaxed. They were familiar with the peers who played their role as students in the classroom. The trainees needed some coaxing, telling, guidance and at times stern looks to make them think, act and ask questions as students would in a normal classroom. This itself was a good eye opener to many, for the first steps in becoming a good teacher is to anticipate the way students would think, behave and ask questions. Such role-play by the peers gave the teacher-trainees an opportunity to start to think the way students in the class would think, without assuming that the students know their fundamentals. This had perhaps been a valuable learning experience to many.

Though each trainee only presented three projects, as the projects were presented to the whole group, there were at least 45 projects that the trainees were exposed to during these presentations. Not only they see these projects; they were also made to comment on the projects. They were free to state the good points as well as the bad ones. The trainees were first made to understand that whatever comments made were made in the interest of improving the project and not for finding fault. Therefore, they were prepared beforehand to accept the comments in the right spirit. After a couple of presentations, the trainees not only got to understand the value of the activity, but also became critical thinkers, made useful suggestions for improvements and modifications to the project and the method of presentation of the project they even commented on the value of the science content taught by their peers.

Slowly, this exercise resulted in the trainees covering those dimensions of science that were previously not included in their learning process. They operated in the process of science domain of Exploring and Discovering, and the important domain of Imagining and Creating that they normally do not use as they only follow instruction without any initiative of their own. In so doing they also learn the application of science to life and other needs, thus developing the Using and Applying domain that makes science meaningful to them. As they were free to make their comments, accept and criticise each other and commend each other wherever the project deserved praise, they also started to develop the right attitudes, values and feelings towards science. Because they were involved in doing projects on their own, they were able to develop the positive 'I can do it' attitude, which is important to give them the confidence that develops the Feeling and Valuing domain in science education. The method of project presentation to the peers helped the trainees to experience all the five domains of the New Taxonomy of Science Education as proposed by McCormack & Yager (1989: 47), thus giving the trainees the opportunity to experience the full spectrum of the richness of science.

4.4 FINDINGS OF THE STUDENT-TEACHER ATTITUDE QUESTIONNAIRE

Teacher-trainees were given a questionnaire entitled "Student-Teacher Attitude Questionnaire" (ST-QR, Appendix II). One set of the questionnaires was administered at the commencement of the course and the other towards the end of the course when they had experienced the doing of projects and presenting them to the class as part of their assignment. The composite summary of the student-teacher responses to the questionnaires given at the beginning of the course (ST-QR-C) and at the end of the course (ST-QR-E) appears as Appendices III & IV respectively. Though the summary shows male (10) and female (5) responses separately for each category, in the following interpretation of the summary, no sex distinctions are considered and the total of the male and female for each option is only taken for analysis. The report that follows is based on the total figures reflected in the composite summary for the questionnaire given at the beginning and at the end of the course to the same group of teacher-trainees at the University of Venda. The detailed report and the researcher's interpretation for the choice of responses by the trainees are given statement by statement for each of the twenty statements in the questionnaire. It must however be noted that the number of teacher-trainees being only 15, the differences in responses at times is not very significant. Further, some teacher-trainees did not respond to certain statements in the questionnaire. Thus based on the raw results of this small sample, clear-cut interpretations may nor be possible.. However, many assumptions made previously can now be confirmed using the responses to these questionnaires. Sometimes the figures received may not be sufficiently significant to give any clue as to the change in the attitude of the teacher-trainees. In making the interpretations, such facts have been considered and the researcher has tried to overlook certain minor deviations to enable him to make meaningful generalisations based on the results, as follows:

STATEMENT 1. Physical science is my favourite subject.

Although one trainee agreed that physical science was not his favourite subject at the beginning of the course, all the trainees either agreed or strongly agreed that physical science was their favourite subject towards the end of the course. This is an indication of the positive change in the perception of physical science as a favourite subject among the teacher-trainees during the year.

STATEMENT 2. The best way to teach physical science is to follow closely the recommended textbook.

At the beginning of the course five out of fourteen agreedwith the above statement. But their response towards the end of the course was different. Every one of the teacher-trainees disagreed with the statement after they had gone through the course. This shows that all the teacher-trainees were convinced at the end of their course that physical science could be taught by methods other than by using textbooks. (Statement 13 is also similar to this statement.)

STATEMENT 3. The experiments in physical science can only be done satisfactorily in a properly-equipped school laboratory.

Twelve trainees agreed with this statement at the beginning and only two disagreed. However, at the end of the course, only four agreed; the rest disagreed, one strongly. This was a clear indication that most of the trainees had realised at the end of the course that experiments in physical science need not necessarily be only restricted to the laboratories and that they could be done even without laboratories for effective teaching of physical science.

STATEMENT 4. The teaching time allocated to physical science will not permit a teacher to do practical work in teaching physical science.

The number of trainees who agreed was the same as the number who disagreed with the statement. The responses at the beginning and the end of the year were also almost the same. From this, it can be assumed that the teacher-trainees were aware of the need for more time for doing practical work and the course itself did not cause any change in their perception of this fact at the end. This is an indication of the real problem teachers of physical science often have with time for preparing and doing practical work. This problem is more acute with less experienced teachers than with their experienced counterparts. The problem can be worse if teachers are not familiar with the working of the apparatus. It could also be bad if there is no equipment and the teacher has to improvise his own apparatus, which is normally time-consuming. One response to the second questionnaire strongly disagreed with this statement. This perhaps might be due to the realisation that not all experiments were time-consuming and even simple experiments could help better understanding of the subject. (For example, dropping of a tiny paper and a coin separately and with the paper on top of the coin to show Newton's Law of Universal Gravitation is simple enough not to be time-consuming, but at the same time very effective to drive home the concept).

STATEMENT 5. Some practical work in physical science is simple enough to be done easily in the classroom.

Two disagreed with this statement, but all the others agreed, five of them agreeing strongly at the beginning of the course. However, their response after they had experienced doing their projects were different: all the teacher-trainees agreed with this statement, and as many as eleven strongly agreed. The idea of introducing the doing of projects and their presentations to their peers was to give the teacher-trainees some feel about the doing of simple experiments, while making them realise that though the experiments may be simple, the understanding it brings about is valuable and it goes a long way in developing the right concepts in physical science. The responses to this statement clearly show that the teacher-trainees at the end of the course realised that there were several simple experiments that could be done in the teaching of physical science. Perhaps they would have also realised the value of the various forms of learning experience they had because of their exposure to doing projects and watching it being presented. Such finer details cannot be anticipated and it will be almost impossible for a lecturer to teach all these during his normal lectures.

STATEMENT 6. I will not do practical work in class, as there is no point in doing some of the simpler experiments leaving out the more difficult ones.

Eleven out of thirteen teacher-trainees disagreed , eight strongly, to this statement at the beginning. This was a clear indication that most of the teacher-trainees were convinced even from the outset that practical work in physical science is useful. The response to the questionnaire at the end of the course showed that all except one disagreed with the statement. This may have been because they were convinced during the course that doing even simple experiments is valuable in the teaching of physical science.

STATEMENT 7. I will do as many experiments as possible in physical science in class, if I am posted to a school that has science equipment.

At the beginning, ten agreed and only two disagreed to this statement. But, at the end of the course, nine agreed and five disagreed. These responses are somewhat puzzling. It appears that there are some teacher-trainees who are still convinced that better student learning of physical science is possible without making students understand the science concepts. They expressed similar views in class during discussions. For them, passing examinations is the objective of student learning and achievement in the subject. Besides, they were not taught that way and so it is difficult for them to see the need to change the way they should teach physical science. There is another interpretation of this statement.

Simply doing as many experiments as possible by itself cannot result in better science teaching or student learning. On the other hand, it could be a way of avoiding the responsibility of teaching physical science in class and wasting valuable teaching time if a teacher is not careful to prepare thoroughly for the practical work in relation to the content being planned for teaching.

STATEMENT 8. If I am to do practical work in physical science in class satisfactorily, I need to be trained in the use of the apparatus found in the school laboratory.

Eight agreed - four strongly - and four disagreed to this statement at the beginning. At the end of the course, however, seven agreed and seven disagreed. The need for further training in doing science has been shown by the responses at the beginning. Having gone through the UED course, it is possible that the teacher-trainees could have been satisfied that they have had the necessary training to handle equipment in a school situation. This may also have been due to the ignorance of the trainees who may not have seen a fully-equipped functional school laboratory. The teacher-trainees in 1994 were especially disadvantaged as they were not exposed to at least some physical science equipment and their use in teaching the subject in a classroom situation because of the disruption caused by the renovation to the physical science laboratory as mentioned earlier. They were not exposed as usual to the use of the equipment this year and so would have gone with the idea that what they know is sufficient for them to function effectively in a school laboratory.

There were instances when teacher-trainees in previous years had made mistakes while doing experiments during teaching practice that could have damaged the equipment and injured themselves and the students in the class. Once, the researcher was fortunate to have been in a class to stop a student, just in time, from opening a tap to wash a test tube with concentrated sulphuric acid heated by the teacher-trainee doing a demonstration in class. This happened because the teacher-trainee was doing the teaching practice in the school that has a laboratory and equipment for teaching physical science. The trainee took the challenge of doing some practical work in class when the researcher visited the school to see him teach. This was commendable. The teacher-trainee no doubt knows the danger involved in adding water to hot concentrated sulphuric acid. But this knowledge is only academic and is divorced from its use in real laboratory conditions, and therefore it never occurred to him at that moment in class when he handed over the test tube of acid to the student to wash. Besides, there is the culture of students being submissive and the teacher telling them to do things, and that prompted the teacher to get the student to do the washing. If the teacher had properly thought out the procedures, and considered the dangers involved in doing the practical work and the precautions that had to be taken - including what to do and what not to do, how to conduct the practical work, and how to seat the students for maximum benefit - most of the dangers of this kind could have been avoided. It would also have made the lesson more enjoyable and meaningful to both the students and the teacher-trainee. Knowing that the trainees had such shortcomings, the researcher posed this question to find out if there was that realisation among them that they needed more training and experience in handling apparatus and doing experiments for them to function as truly professional teachers. This message did not seem to have been passed on to the trainees in 1994 from the response to this question. This might have been caused by the lack of opportunities to work in the physical science laboratories this year due to the renovation to the physical science laboratories.

STATEMENT 9. Students benefit from their learning of physical science even if only few practicals are done in class.

Majority of the trainees disagreed with this statement, three strongly, at the beginning. But after the course, no one strongly disagreed. Nine agreed, two strongly with this statement. These responses show the shift in their thinking that can induce them to do at least some practical work in their teaching that can make a difference to the teaching and learning of physical science in class. This realisation should also have been influenced by the trainees doing and presenting projects as part of their course work.

STATEMENT 10. The extra effort and energy spent in doing practical work in physical science in class is not worth it.

At the beginning of the course, four agreed, one strongly, with this statement. At the end, however, no one agreed with this statement. As many as ten strongly disagreed, showing that the trainees had been influenced during the course to see the value of doing practical work in the teaching of physical science. This also shows that the trainees are convinced that extra energy and effort put into doing practical work in class are rewarding and worthwhile.

STATEMENT 11. As it is expensive to do practical work in a science class, it is not worth doing practical work in teaching physical science.

Almost identical responses were obtained at the beginning and at the end, for this statement. The majority strongly disagreed with this statement, thus showing that they were generally convinced that expenses should not prevent the doing of practical work in the teaching of physical science in class. In other words, they have shown that they fully realise the need for, and the worth of, doing practical work in teaching physical science. Though no one disagreed at the beginning, one strongly disagreed with the statement at the end. This could have been because this person realised that doing experiments need not be expensive as demonstrated by the projects they did during their course.

STATEMENT 12. Teacher demonstration experiments in class are not helpful in teaching physical science.

The majority disagreed with the statement. There was no noticeable difference between the response at the beginning and the end of the course. It could be because the teacher-trainees saw and performed demonstrations, and realised their value in teaching science even before they started this course. They were further convinced of this method due to their presentation of the projects that were mostly teacher demonstrations.

STATEMENT 13. Students who have access to textbooks understand physical science, even if they do not do any practical work in class.

With this statement, six agreed and eight disagreed at the beginning. At the end, five agreed and nine disagreed. Though there is some positive change of attitude towards the use of practical in class, there is still a strong feeling that textbooks are essential to understand physical science. There is no doubt that books help learning any subject, including physical science. Besides, it is textbooks that have helped all these trainees to have accomplished this much so far and they cannot deny this fact, although they have seen the value of practical work in science education. The emphasis in this statement is understanding science that can result both from doing experiments and by reading about them in the textbooks. (Also refer to Statement 2.)

STATEMENT 14. Practicals are not useful in teaching physical science in class, as the answers obtained are usually not accurate.

The responses to this statement were almost the same both at the beginning and at the end of the course. There was a positive shift in the degree of disagreement to the statement showing that at the end the trainees were more aware of the importance of doing the experiment rather than obtaining accurate practical results.

STATEMENT 15. The time wasted by a physical science teacher in preparing to do practical work in class could be profitably used by the teacher to teach the syllabus.

This statement was somewhat unfair as it could have been interpreted by different trainees differently. On the face of it, this statement is true and only proper they agree to it. The time used in preparing for practical work is usually outside the teaching time and if a teacher could use that time for teaching, even using the drill method, it would perhaps produce better results. But it is doubtful if this is better learning. On the other hand, time is needed for preparing to do practical work and so time spent in preparation cannot be considered time wasted. Twelve disagreed with this statement at the beginning and eleven at the end of the course. The disagreement was because they did not consider the time spent in preparing for practical as time wasted, and they realised that teaching of the science syllabus without using the practical approach would not be beneficial in teaching science.

STATEMENT 16. Experiments done in class are only useful if they give accurate and convincing results as in the textbook.

This statement is similar to Statement 14 discussed before. The responses before and after were also somewhat similar. Most agreed that accurate results as in the textbook are not the criterion for judging the usefulness of doing experiments in class. Much learning is possible from inaccurate experiments and from the mistakes in one's experiments as demonstrated to the trainees during their project presentations. This could have been the reason for the majority disagreeing with this statement. (Also see Statement 14.)

STATEMENT 17. I hate to think of doing practical work in class, as so many things could go wrong in class while I am in front of the students.

All but one disagreed, showing that they are open for correction, criticism and improvement. There were two who changed from disagree to strongly disagree after the course, showing a shift in their attitude to accept the possibilities of erring by the teacher in front of the class. The shift in their position - to accept faults, make mistakes and still be willing to do experiments in front of a class - could have been attributed to the effect of the project presentations and the acceptance of the constructive criticisms of the project by their peers.

STATEMENT 18. Physical science must be taught by doing practical work in class, for effective learning of the subject.

All except two agreed to this before and after the course showing that the trainees were quite aware of the importance of teaching physical science as a doing subject.

STATEMENT 19. As a student, I did not do any practical work and so I do not see any point, when I start teaching, in forcing my students to do practical work in physical science in class.

All the trainees disagreed with this statement both at the beginning and at the end of the course. They are indeed convinced that students need to experience science though they were not fortunate to experience it themselves as a doing subject when they were students at school. The response shows the realisation of the importance of practical work in learning physical science.

STATEMENT 20. Importance need not be given to practical work in class in the teaching of physical science.

The majority disagreed with this statement both at the beginning and at the end. This shows that the trainees are aware of the importance of doing practical work in class in the teaching of physical science.

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CHAPTER 5

IMPROVISED EQUIPMENT IN TEACHING PHYSICAL SCIENCE

5.1 INTRODUCTION

To find out the impact of using improvisation in a real teaching situation, first, an in-service training of teachers of physical science in certain selected schools in Venda was carried out. The in-service workshops were for the effective use of improvised equipment in the teaching of physical science at senior secondary level. In order to evaluate the changes in teacher attitude towards the use of improvised equipment in the teaching of physical science, the participating teachers were given questionnaires before and after the in-service workshops. The in-service training enabled the teachers to use improvised equipment with the students in their schools while teaching physical science.

In order to know if the use of improvised equipment by the teachers in teaching physical science in their schools brought about any change in student attitude towards their learning of physical science, questionnaires were given to the students. One was given before they were taught with the improvised apparatus and the other after they had been exposed to the use of improvised equipment in their schools. The questionnaires were administered to the students at these schools at the standards 8, 9 and 10 levels, although initially it was meant for standards 8 and 9 students only as mentioned in the letter sent to the Director General of Education asking for permission to use the schools for the research. However, as most of the inset was directly relevant for standards 9 and 10 students, the responses from the standard 8 students have not been considered for the final analysis of the findings that are included in this chapter.

5.2 SELECTION OF SCHOOLS

Application for permission to involve teachers in service in this research project was made to the Director General of Education and Culture, Department of Education, Venda, on 21 April 1993 (Appendix V). The reply granting permission for the use of teachers and the school pupils for this research was dated 30 June 1993 (Appendix VI). The Subject Advisory Services of the Department of Education, Venda, was good enough to assist in selecting two schools from each educational area at random, which do not have equipment for doing science, inform them through the right channels, and make the preliminary arrangements for the workshops that were arranged (letter dated 20 Sept. 1993 (Appendix VII)).

The first workshop was held on 13 October 1993 in the Physical Science Methodology Laboratory at the University of Venda. The chief guest that day was the Chief of the Subject Advisory Services, Mr.N.M. Rathando of the Department of Education. The Dean of the Faculty of Education, Professor K. W. van Heerden, welcomed the teachers for the in-service workshop. The Subject Advisor of Physical Science, Mr. M. S. Netshiozwei, attended not only this first in-service workshop but also the second one held on 25 March 1994 in the media centre of the library of the University of Venda.

Two schools from each of the six educational areas in Venda were selected for this course. Table 5.1 gives the details regarding the teachers registered for the first inset workshop.

Originally 17 teachers from 12 schools were invited to attend the in-service workshop. On the day of the in-service workshop, only 15 teachers were present to register for the workshop. Three schools sent two teachers each, for the first in-service workshop.

AREA	SCHOOL	TEACHER/S
MUTALE	HANYANI RATSHIBVUMO	Mr. Magidimisa, A.R Mr. Ndou, T.W
MUTSHINDUDI	TSHADAMA FUNZWANI	Mr. Mphaga, N.T Mr. Makharamedzha, S.E & Mr. Maumela, M.E
NZHELELE	SOLOMON MAELULA RAMASHIA	Mr. Mudau, T.A & Mr. Sundani, N.B Mr Netshikweta, A.C & Mr. Mulaudzi, N.D
THOHOYANDO	DIMANI WILLIAM THEMELI	Mr. Jat Egen. Mr. Nelufule, A.F
TSHITANDANI	LISHAVHANA TSHIKHUTHULA	Mr. Mudzhigi, N.R Mr. Mutemula, S.A
VUWANI	KOLOKOSHANI MASWIE	Mr. Sukumani, M.P Ms. Mashamba, R. E

TABLE 5.1 TEACHERS REGISTERED FOR THE FIRST INSET WORKSHOP, 1993.

The teachers were introduced to the need for the learning of science by doing and the cultivation of the scientific methods that went hand-in-hand with practical work in science.

Having been introduced to the need for doing practical work in science, they were introduced to the type of activities that they could do in class using improvised equipment. They were given a chance to familiarise themselves with the equipment so that when they were supplied with similar equipment, they should be able to use them comfortable in class and to the advantage of teaching physical science effectively. This exposure should enable them to teach science by doing, exploring and investigating, rather than by using the traditional telling method. The grant available for this research from the Research and Publications Committee of the University of Venda was used mainly for travelling expenses for the teachers and for the construction and supply of the apparatus needed for this project so that the programme could be successfully carried out in these schools.

5.3 INSET WITH TEACHERS

An in-service course with the teachers selected for this project was held twice though initially a series of in-service courses were planned. This reduction was mainly due to the lack of funds for the payment of travelling expenses for the teachers, which far exceeded the initial estimate. More in-service sessions would have had a better and long-lasting effect on the teachers and would have enabled them to do these activities with more experience in class, which would have resulted in better student learning of the subject. There were other interruptions including frequent school boycotts due to the demand for the refund of pension money by the teachers and other civil servants as well as preparations for the first democratic national election countrywide early in 1994. It was therefore impossible to have more in-service courses even if resources were available. Although only two in-service workshops were held, they were conducted for the whole of the morning session on each day. This gave the teachers time to be exposed to the equipment. They were able to handle the equipment and become familiar with them so as to enable them to use them comfortably in their schools.

The first inset was conducted on 13 October 1993, starting from 09h00 with a half hour break for tea at 10h30 and went on until 13h30. The participants were provided lunch from the funds of the Dean of the Faculty of Education. The second in-service workshop was conducted on 25 March 1994 in the Media Centre of the Library of the University of Venda instead of the physical science methodology laboratory. This was because the latter was undergoing revamping in 1994 and was therefore unfortunately not available for use. This in-service workshop also started at 09h00 and ended at 13h30 with a half hour break for tea.

Information to the teachers was sent by mail and written acknowledgements received in time on the first occasion. The second in-service workshop announcement also went out by post, but as there were disruptions at that time of the year, an announcement was also made over the local radio station (Radio Thohoyandou) regarding this workshop. In this announcement, although the names of schools were mentioned, seven teachers from schools not registered for this project were also present at this second in-service workshop. This is an indication of the enthusiasm teachers of physical science have in such in-service workshops. This also indicates the need for having in-service training for physical science teachers in Venda. All the teachers who responded to the invitation were accommodated at this second workshop. This second workshop was held after the registered schools were supplied with the necessary equipment for doing the experiments with improvised equipment. The travelling expenses for attending this inset workshop was paid only to the teachers who were previously registered for this project. The others were quite pleased to have attended this inset, though they were not reimbursed their travelling expenses. They expressed the great need that existed in this region for such in-service workshops to improve the teaching of physical science in Venda. They requested that they be invited for future workshops of this kind.

The inset was planned to provide teachers with the necessary information for doing all the experiments in the mechanics section of the syllabus. This covered the standards 9 and 10 syllabi using totally improvised equipment. This section is considered to be one of the most difficult and abstract sections by many students and teachers. They have difficulty understanding the fundamental concepts using such apparatus as ticker-timers, trolleys and collision apparatus to do their experiments in the laboratories and relate them meaningfully to the theory they have studied from their textbooks. Teachers also do these experiments mechanically: they do not understand the concepts and principles involved and simply apply the procedures suggested by the textbook in doing the experiments. The improvised apparatus was made from materials obtained from the hardware shops. These could easily be turned out by any teacher who has some skills and ability to cut, plane, screw and join wood. Many students can produce such apparatus if they are given a chance to make them. There were several other simple apparatus that the teachers could make on their own to conduct experiments in physical science using simple materials obtainable from home and workshops. These experiments could be used at different levels and enhance better understanding of the subject to both the teacher and the students. The teachers were asked to try them out and use them in their teaching whenever they could. To help them do some of these experiments, they were supplied with some basic materials like balloons, insulated winding wires, marbles and milk bottles.

At the second inset, the teachers were given the necessary practical exposure to enable them to be comfortable in using this method in their classroom teaching. The supplied equipment was for use mainly by the standard 9 and 10 pupils. However, interested teachers could have turned out apparatus from the information supplied to them at these workshops in order to teach physical science as a doing subject at any level. There were some experiments in the information sheets supplied that are suitable for use by the standard 8 students as well. At the end of the second inset workshop, teachers were instructed to use these and other experiments whenever they could in their teaching. They were requested to administer the second questionnaires after they had done their teaching of physical science in class using the various improvised apparatus. The teachers also had to answer a questionnaire once they had used the improvised equipment in class teaching.

There were unfortunately some changes in the staff that had taken place since the first in-service workshop in October 1993. Teachers from five schools registered for this in-service workshop were not available in 1994. The researcher came to know later that one teacher had gone on study leave, another had been relieved of the duties of teaching of physical science in senior classes, another had been transferred to some other school and one had left the teaching post. As a result, new teachers were present for the second inset workshop in place of the ones who had attended the first. This made the second inset somewhat difficult to start from where it was left before, without repeating some work done earlier. This caused some unexpected problems in the carrying out of the planned programme. It was also clear that in at least some schools, the equipment supplied was not adequately used. This is due to the lack of know-how on the part of the new teachers. As a result, the teacher attitude questionnaires had to be only restricted to those schools where there was continuity of the teachers involved in the in-service workshops and the student attitude questionnaires had to be eliminated from those schools where the improvisation was not carried out as expected. Thus, student attitude questionnaires for this study are also taken for analysis only from seven schools.

5.4 FINDINGS OF THE TEACHER-ATTITUDE QUESTIONNAIRE

Questionnaires were given to teachers who took part in the project, before and after the in-service workshop. These questionnaires were similar to the student-teacher attitude ones (ST-QE) described in Chapter 4, but the questions were modified where necessary to suit the teachers. Appendix VIII is a sample teacher attitude questionnaire (T-QR).

Though there were 15 teachers taking part in this project initially and the first questionnaires were collected from all of them, due to the reasons mentioned previously, only eight teacher responses are taken for analysis in this section. These teachers are from seven schools.

The number of teachers from whom questionnaires were obtained for this study being small (8), the responses do not appear to be very significant for some questions. The summary of responses to the 20 questions is given as Appendices IX and X for the responses to the two questionnaires: one given before the in-service workshop (T-QR-C) and the other given after they had used the improvised equipment in their schools (T-QR-E) respectively.

The difference in the responses between the first and the second sets of questionnaires for seven of the statements was not very distinct. There were clear difference between the responses to the statements in the first and the second questionnaires. The summary of these teacher responses may be interpreted as follows:

STATEMENT 1. I enjoy teaching physical science.

All the participants agreed, most of them strongly, with this statement both before and after the in-service workshops. In the second questionnaire, one dropped from 'strongly agree' to 'agree'. Perhaps this teacher lost some enjoyment after doing the practical work with the students.

STATEMENT 2. The best way to teach physical science is to follow closely the recommended textbook.

The same number of teachers agreed and disagreed both in the first and the second questionnaires. The in-service workshops did not alter their view regarding the use of the textbook as the main aid for teaching physical science. This might be partly due to their background in the subject content and partly to the method their teachers had used to teach them when they were students.

STATEMENT 3. The experiments in physical science can only be done satisfactorily in a properly-equipped school laboratory.

Many teachers and students have this notion. This could also be an excuse for not doing practical work in classroom teaching. During discussions, many teacher-trainees often expressed this view as the most important reason for their not doing practical work in their teaching. Before the in-service workshops, six of the teachers agreed to the statement - three strongly - and only two disagreed with this statement. In the responses after the in-service workshops all the teachers disagreed with this statement. This is an indication that the teachers were convinced that experiments can satisfactorily be done in the classroom and that laboratories are not essential for doing practical work. The idea of using improvisation in constructing apparatus is to help the teachers realise this. Because of this realisation, they will be motivated to do experiments in class. There are several simple experiments that can be done in a classroom to promote better student understanding of the subject.

STATEMENT 4. The teaching time allocated for physical science will not permit a teacher to do practical work in teaching physical science.

Six teachers agreed, one strongly, and only two disagreed to this question at the beginning. This is because teachers do not conduct experiments and they think that experiments take time. Even in those schools where there is equipment for doing practical work in physical science, many teachers have been observed to teach the theory so as to finish the syllabus first. Once this is done, if time is available, the students are shown the experiments relevant to what was taught theoretically to them. This has its disadvantages (and perhaps some advantages). But it is a method that does not help students to get the right feel about science, learn science by doing and forming concepts. They do not learn the scientific methods, approaches and attitudes, and thereby know their applications in real life.

After the in-service workshops, the teachers responded differently. Five teachers disagreed with this statement, one strongly; only three still agreed. This shows a shift in the attitude of teachers who now felt that physical science teachers could still do practical work in class within the allotted time. To achieve this, teachers have to prepare themselves thoroughly so that the practical work forms an integral part of their teaching and their lesson plan includes the proposed plan for the practical work as well.

STATEMENT 5. Some practicals in physical science are simple enough to be done easily in the classroom.

Two teachers disagreed with this statement, while six agreed, one strongly, at the beginning. This shows that though some teachers think that practical work is difficult, many teachers know that some experiments are simple enough to be done in the classroom. After the in-service workshops, all the teachers agreed to the statement, six of them strongly. This shows a definite change in their attitude towards doing simple experiments in the classroom while teaching physical science.

STATEMENT 6. I do not do practicals in class, as there is no point in doing some of the simpler experiments leaving out the difficult ones.

At the beginning there were five teachers disagreeing with this statement and three disagreeing strongly. At the end, two disagreed and the rest disagreed strongly. This shows that the teachers who are in the field are convinced that all experiments, including even the simple ones, should be done, and are of use in teaching physical science. This shift in emphasis after the in-service workshops shows that the teachers were convinced of the advantages of doing even simple experiments that have great effect on student learning. This is because it can lead to student understanding and help in the formation of science concepts that can be usefully applied under different conditions.

STATEMENT 7. I would have done as many experiments as possible in physical science in class, had my school had the science equipment.

All the teachers agreed with this statement both at the beginning and after the in-services were held. This shows that these teachers are interested in doing experiments, but as they have no facilities, they have not been doing them.

STATEMENT 8. I would have done some experiments in physical science, had I known how to set up the apparatus to do those experiments.

Only two teachers agreed to this while six disagreed at the beginning. After the in-service workshops, three agreed, one strongly. The majority stuck to this before and after the course. However, the change in attitude after the in-service workshop is significant as at least one more teacher changed his position expressing the need to know more, to be able to set up apparatus for experiments.

STATEMENT 9. Students benefit in their learning physical science even if only few practicals are done in class.

At the beginning, four agreed and the other four disagreed. After the in-service workshops, six agreed, one strongly, and only two disagreed. This is a definite shift in their perception of the effect of practical work in the teaching of physical science. This understanding is important to encourage the teachers to try to do as many experiments as possible even if it means that they are going to do only few experiments. Few experiments can also give the students the feel of doing science. Once they have seen that doing experiments is, after all, not that difficult, and it does indeed help in better student learning and understanding, they will be encouraged to do more experiments.

STATEMENT 10. The extra energy and effort spent in doing practicals in physical science in class, are not worth it.

To this statement, all teachers disagreed at the beginning and at the end of the workshops. That means the teachers think that this subject is not burdened with too much work. All teachers need to put in more effort and energy to make their subject more enjoyable and meaningful and this is also true of physical science. This fact seems to have been acknowledged by the teachers of physical science too, according to their responses. However, there was one who shifted from 'strongly disagree' to 'disagree' after the inset workshops. It makes one wonder if this teacher has now realised that there is greater burden in teaching physical science and that there is a need to put in more effort and energy into doing experiments in teaching.

STATEMENT 11. As it is expensive to do practicals in a science class, it is not worth doing practical work in teaching physical science.

All the teachers disagreed with this statement both at the beginning and after the in-service workshops were held. One response shifted from strongly disagree to disagree after the in-service workshop. The disagreement shows that the teachers feel that doing experiments in teaching physical science, though expensive, is worth it.

STATEMENT 12. Teacher demonstration experiments in class are not helpful in teaching physical science.

All the teachers disagreed with this statement. These responses supported the teacher realisation of the importance of demonstration of experiments in class to make the subject clear to the students. At the beginning, there were only three who strongly disagreed, while after the in-service workshops, five strongly disagreed. This shift shows that the teachers are now convinced that teacher demonstrations that are possible with many improvised equipment have their value in classroom teaching.

STATEMENT 13. Students who have access to textbooks understand physical science, even if they do not do any practicals in class.

At the beginning, two teachers agreed and six disagreed with this statement. After the in-service workshops, all the teachers disagreed, three strongly. This perhaps is because these teachers have learnt that doing practical work is helpful in their understanding of physical science. This realisation after they had the chance to experience first-hand that understanding goes with doing practical work. This is a very important understanding by the teachers to help them try to use a practical approach to the teaching of physical science in class. This can also help the teachers to move from a textbook-oriented learning activity to an investigative type of learning. Such learning will teach the students several principles and disciplines that should be followed by students to make them think and function as scientists.

STATEMENT 14. Practicals are not useful in teaching physical science in class, as the answers obtained are usually not accurate.

All the teachers disagreed with this statement both before and after the in-services. This shows that they acknowledge that practical work is useful in teaching physical science. They are also not so concerned with the accuracy of the results because they are trying to teach the concepts through practical work, not find the correct answer or value. Accuracy is always relative, not absolute. It could always be improved depending on what level of accuracy is required for a particular purpose. What is significant in the responses is that at the beginning, three strongly disagreed, while at the end, six teachers strongly disagreed. This shows that by the end of the workshops, they had realised the importance of doing practical work in the teaching of physical science. Obtaining accurate results should not be the aim of practical work in class.

STATEMENT 15. The time wasted by a physical science teacher in preparing to do practicals in class could be profitably used by the teacher to teach the syllabus.

At the beginning, three teachers agreed with this statement, while five disagreed. This is understandable as teachers still view practical work to be a waste of time. Since teaching had always been by the telling method and textbook-centred, they agreed to this. After the in-service courses, all the teachers disagreed, three strongly. This is an indication of their realisation that for student understanding in physical science, practical work is necessary and that mere telling does not lead to proper student learning.

STATEMENT 16. Experiments done in class are only useful if they give accurate and convincing results as in the textbook.

Fifty percent of teachers agreed with this statement both before and after the in-services. Apparently many teachers still feel that their teaching should conform to the content of the textbook; the others feel that even if accurate results are not obtained, experiments are useful. This also shows the strong desire some teachers have for getting the expected results when doing experiment. What is important at this level is for the understanding of the concepts through practical work. The results need not be accurate. It will be advantageous to know the possible reasons for the inaccuracies in the results.

STATEMENT 17. I hate to do practicals in class, as so many things could go wrong in class while I am in front of the students.

All the teachers disagreed with this statement and the numbers remained the same before and after the in-service workshops. This shows that the teachers are not opposed to doing practical work in class. They are even ready to face some humiliation when things go wrong in front of the class. This positive attitude is good and these teachers can probably teach well, provided they get the opportunity to do experiments in class.

STATEMENT 18. Physical science must be taught by doing practical work in class for effective learning of the subject.

All the teachers agreed with this statement before and after the in-service workshops. This shows that the teachers are aware of the importance of doing practical work in class. They are willing to help their students do better than themselves. They want their students to do practical work in learning physical science.

STATEMENT 19. As a student, I did not do any practical work in class and so I do not see any point in forcing my students to do practical work when I teach physical science today.

All the teachers disagreed with this statement before and after the in-service workshops. Four teachers disagreed strongly before, but six of them disagreed strongly after the in-service workshops. This shows several good points about the teacher attitude change. The responses to this statement clearly indicate that teachers realise that doing experiment is important for the proper learning of physical science. They also show that the teachers are quite willing to correct what wrong was done to them in the past, in the interest of better student learning. This attitude change prompted some to disagree strongly to this statement after they had experienced science by doing experiments in their in-service sessions.

STATEMENT 20. Importance need not be given to practical work in class in teaching physical science.

All the teachers disagreed with this statement, both before and after the workshops. They were convinced right from the beginning that practical work in class is important in teaching physical science.

5.5 FINDINGS OF THE STUDENT-ATTITUDE QUESTIONNAIRE

The responses received from students in seven schools are analysed below: These schools belong to five education areas of Venda. The number of students doing science in schools in Venda is usually small. There are generally larger numbers of students doing science in the lower standards than in the higher standards. Standard eight responses to the questionnaire are not considered for this analysis as teachers did not do experiments in science with students at that level. The in-service workshops used syllabi from standard 9 and 10 especially to cover the mechanics section. Besides, as the number of workshops was reduced to two because of interruptions in school in 1993-94, teachers could not get sufficient information to help them do experiments with their standard eight students. Table 5.2 gives the details regarding the student numbers in each standard taken for the analysis of student responses in this section.

AREA	SCHOOL	STUDENT NUMBERS		TOTAL
		STD 9	**STD 10**	
MUTALE	HANYANI	4	0	4
MUTSHINDUDI	FUNZWANI	7	2	9
MUTSHINDUDI	TSHADAMA	8	4	12
NZHELELE	RAMASHIYA	1	16	17
THOHOYANDOU	WILLIAM THEMELI	24	0	24
VUWANI	KOLOKOSHANI	9	8	17
VUWANI	MASWIE	12	12	24
TOTAL		65	42	107

TABLE 5.2 STUDENT NUMBERS CONSIDERED FOR ANALYSIS AND INTERPRETATION OF THE STUDENT-ATTITUDE QUESTIONNAIRES.

The numbers of students responding to each statement in the questionnaires are converted into percentage values. This is to help make easy comparisons between the two questionnaires given, one before the in-service workshop (S-QR-C) and the other after (S-QR-E). Appendices XI (S-QR-C) and XII (S-QR-E) give the student responses as percentage for each option for each statement in the questionnaire for the first and the second questionnaires respectively. The twenty statements in the student attitude questionnaire (Appendix XIII, S-QR) are similar to those in the teacher attitude questionnaire (Appendix VIII, T-QR), but the former have been modified to suit the students.

The following comments are the researcher's interpretations of the responses of the students to these two questionnaires. The difference in responses result from the teachers doing experiments in class using improvised equipment supplied to the schools. In the following interpretations it is assumed that the other variables have remained somewhat unchanged during this period:

STATEMENT 1. Physical science is an interesting subject.

Quite surprisingly the response to this statement was positive. The number agreeing before the inset is only 50%. It went up to 70% after the inset workshops. This shows that student interests went up after the teachers had done experiments with the improvised equipment. The fact that 50% initially said that this was an interesting subject shows that these students decided to offer it out of their interest. Therefore they are motivated from within to learn. It is the duty of the teachers to ensure that their motivation is kept up. Their interest must be sustained so that the best use is made of their interest while teaching this subject.

STATEMENT 2. The best way to learn physical science is to follow closely the recommended textbook.

At the beginning, 68% agreed to this statement, but after the use of the practical approach, only 29% agreed. At the beginning 32% disagreed with this statement, but in the second questionnaire, this disagreement went up to 71%. This difference is a change in attitude among students. They have started to believe that besides the textbooks, there are other aids that can assist students in the learning of physical science.

STATEMENT 3. The experiments in physical science can only be done satisfactorily in a properly-equipped school laboratory.

Only 10 percent of the students initially disagreed with this statement. This shows that they were convinced that they cannot do practical work without facilities. The students had the opportunity to see the teacher do experiments using improvised equipment. This enabled 57% of the students to show a definite change in their attitude by disagreeing with this statement.

STATEMENT 4. The teacher may not be able to complete the syllabus in physical science if he starts doing experiments in class.

To this statement 40% agreed at the beginning. After the in-service workshops, only 33% agreed and all the others disagreed, 19% strongly. There is no doubt that teachers find difficulty in completing the syllabus, especially in science and mathematics. This is further worsened by the many disturbances that occur in the schools in Venda during the year. Teachers find it difficult to finish the syllabus, and students fear that if a teacher takes on any further responsibility, it is going to adversely affect their chances of completing the syllabus. However, after the in-service workshops, students realised that teachers could complete the syllabus even after doing experiments in class. This is because the learning by doing experiments is different from the learning in the traditional classroom. Students realised that the doing method is better than the former method. The responses to this statement should also be examined along with the responses to the next statement, as they are related.

STATEMENT 5. Some practicals in physical science are simple enough to be done easily in the classroom.

To this statement 66% disagreed at the beginning but after they had been exposed to improvised experiments, only 15% disagreed - an increase of over 50% of students agreeing to it. A large number of students realised, during the workshops, that experiments can be done in the classroom without expensive equipment. This has been the main idea of introducing this method in improving the teaching of physical science in schools in Venda.

STATEMENT 6. The more difficult practicals in physical science are the ones that should be done to help us learn physical science properly.

At the beginning, 77% of students agreed with this statement. Perhaps they were under the false impression that simple experiments involved simpler and easier sections of the content and that more difficult experiments only needed to be done to help them learn the difficult sections in physical science. Difficulty is a relative term: what is difficult for one may be easy for another. Perhaps there might have been some confusion with regards to this statement. Almost the same percentage of students agreed with it before and after the practical work was done in class. Practical work did not have any influence on the students' attitude in this regard.

STATEMENT 7. My teacher would have done some experiments in physical science in class, had there been science equipment in my school.

Half the student population agreed with this statement. Perhaps, students' confidence in their teacher and his ability to do experiments might have accounted for their agreeing with this statement. After the experiments in class with improvised equipment, about 9% more agreed with this statement. Having seen the teacher do experiment, these students were convinced that the teacher could do experiments if there was equipment in their school. However, equipment in school does not necessarily ensure that the teacher will do the experiments in physical science lessons. Perhaps this doubt is still in the minds of students. They need more time and proof that the teacher will continue to do demonstrations and experiments in class. Then, larger numbers will agree with this statement.

STATEMENT 8. I will understand physical science better if my teacher does experiments in class.

Again many students (64%) agreed with this statement at the beginning and it went up to 89% at the time the second questionnaire was given. This is a clear indication of student interest in practical work. After taking part in experiments in class, they become more convinced of their advantages.

STATEMENT 9. The experiments done by my teacher in class helped me in better understanding of physical science.

This statement drew 43% agreement from students. Perhaps this is because some teachers appear to have done some experiments in some schools. After the experiments were conducted by the teachers following the inset sessions, this number increased by 40%. This is a good indication of the impact of improvised equipment on student understanding of physical science.

STATEMENT 10. The extra effort and energy spent by my teacher in doing practicals in physical science in class is not worth it.

At the beginning only 32% disagreed with this statement, but following students' exposure to practical work, 68% disagreed with it. This increase in the number disagreeing with this statement implies that doing experiment in class is worth it.

STATEMENT 11. I do not think that the amount of money spent in doing practicals in class in learning physical science is worth it.

This statement must also be seen in relation to statements 8, 9 & 10 as they are related to each other. Initially 64% disagreed with this statement; after the practical work, 69% disagreed. A large number of students disagreeing with this statement as in the case of Statement 10 is an indication of their perception that money must be spent for better student learning of physical science by doing. Similarly positivew attitudes shown in responses to Statements 8 and 9 show that they are keen in doing experiments, though it is not being done at present in class. Whether or not practical work really helps students to learn better can only be seen by other means not attempted in this questionnaire.

STATEMENT 12. I like to watch the teacher do the experiments as it is troublesome to do them myself.

There was agreement to this statement from 73% of the students at the beginning. After the in-service workshops, 66% responded saying that they would rather do the experiments themselves. They perhaps did not feel that it was troublesome to do experiments. The nature of improvised apparatus is that experiments using them involves several students. Such involvement of students helps to remove the fear of doing experiments. Doing experiment is therefore not troublesome.

STATEMENT 13. If I have science textbooks, I will understand physical science even if I do not do any practicals in class.

Majority of students agreed to this statement at the beginning of the workshops. This also shows that students do not have textbooks in many schools and would like to have books from which they can learn. They are also used to learning from the textbooks and therefore believe that textbooks are important. Therefore, they do not see the relation between practical work and learning the subject. However, after the in-service workshops with the teachers, 54% agreed as compared to 72% at the beginning. This improved attitude can be ascribed to these students realising that they understood physical science concepts better in those areas where experiments were done. This is a small but important step to enable these students to realise that science should be learnt with understanding and by doing. This will make them realise the disadvantage of studying the content from textbooks.

STATEMENT 14. Doing experiment in class is not useful in learning physical science as the results of such experiments are usually not accurate.

At the beginning, 68% agreed with this statement and only 32% disagreed. The students do not have a concept of accuracy and so they feel that getting the value of the information in the textbook is solely important. Perhaps this is what the teachers have also been advocating in class. But the emphasis in the inset workshops with teachers had been to inform them that what is essential for them to teach is to make the students understand the concepts that are involved in the experiments. This will enable them to know what they are learning and then it will have meaning for them. This is in keeping with the thinking that "thoughts without content are empty. Perceptions without concepts are blind" (Wellington 1989: 1). In the second questionnaire, only 31% agreed. There is a 37% increase in students disagreeing with the statement. This shows that in doing experiments, the teachers have emphasised the understanding of concepts instead of getting accurate results. It has brought the change in attitude in 37% of students who have, as a result, disagreed with the statement.

STATEMENT 15. We could benefit more if the time spent in the preparation for practical work by the teacher is devoted to teach us more physical science content in class.

Before the in-service workshops more than 50% of students agreed with this statement. The students perhaps felt that for them to benefit, more teaching was essential. However, a 3% increase is noticed in the disagreement between the two questionnaires. This shows some realisation among students concerning the importance of doing practical work in physical science.

STATEMENT 16. Experiments are only useful if they give the same answer as in the textbook.

At the beginning 70% of students agreed with this statement but after the experiments only 35% agreed. This statement is also related to statement 14. The responses there, too, are similar to the ones for this question. This is due to the realisation that what is important in science education is the doing of experiments and understanding the subject and not confirming the answers found in textbooks.

STATEMENT 17. While doing experiments, many things can go wrong and therefore much cannot be learnt from practical work in physical science.

At the beginning 67% disagreed. This could have been because of ignorance or the fact that they felt that much learning was possible by doing experiments though they had not had a chance to experience it so far. At the end of the workshops, 78% disagreed with this statement. The improvement shows that they realise that doing experiments is useful in physical science.

STATEMENT 18. I learn many things when I do experiments in physical science even if I do not get accurate results.

Only 29% agreed with this at the start but 67% agreed with this after they had done the experiments with improvised equipment in class. This is a definite indication of their acceptance of this fact and it is also linked with Statements 14 and 16 that also gave similar student responses.

STATEMENT 19. I hate to do science projects as I am not good at doing things with my hands.

Large numbers (77 % at the beginning and 70% at the end) disagreed with this statement. This shows the interest students have in doing experiments by themselves. This is also linked to the answers given to Statement 1 concerning the interests students have in physical science. The reduction of 7% after the exposure to improvised equipment is somewhat difficult to understand. This could have been the result of the need to function collectively while working with improvised equipment. Also, students had not been exposed to producing improvised equipment. They could have a fear that this is difficult and so the numbers responding positively could have increased.

STATEMENT 20. Importance need not be given to doing practicals in class in the learning of physical science.

At the beginning 52% of students disagreed and at the end 59% disagreed with this statement. Students however still feel that physical science can be learnt without doing experiments as over 40% responded this way.

The use of improvised equipment is not part of the way these students have been learning previously. It was more a novelty, a trial, a way of learning science differently. For the teachers too, it had been a different way of teaching science. The teachers should be convinced that this method is a better method of teaching the subject. This change has to take place first in the understanding of the teachers; then they should carry out this process approach with ease and enthusiasm and ensure that teaching is for the understanding of concepts and the process involves the development of several other faculties of the students. These faculties include the cognitive, psychomotor and the affective domains. It exposes students to the use of science in daily life and to its application for the betterment of human kind. If these can be done, then student learning will also be meaningful. The subject will be learnt with the desire that will enable the students with such interest in science to do well. This, in turn, will relieve this country of the existing shortage of qualified science-based personnel at all levels of its man-power needs. This advancement will reduce unemployment and bring prosperity to many.

5.6 TEACHER RESPONSES TO THE END OF INSET QUESTIONNAIRE

Teachers who took part in the last in-service workshop in March 1994 were given an end-of-inset questionnaire (Appendix XIV). The responses received for this questionnaire offered much insight. It showed their needs, the usefulness of the in-service workshop, the content covered, their perception of the advantages and disadvantages of the methods employed in the workshop, their needs for further training and improvement.

Twenty-two (22) teachers attended the final workshop. This number, as mentioned earlier, included those seven teachers who responded to the announcement over Radio Thohoyandou regarding this in-service workshop. They were not initially registered for this in-service.

Everyone agreed that the in-service workshops had been useful and they had gained much knowledge and experience. They expressed the view that they would now be able to do many experiments even without laboratories and equipment in a normal classroom. The teachers also wanted similar experiments in chemistry. Some experiments in chemistry were included in the information sheets supplied at the workshops. However, the main emphasis at these in-service workshops was on teaching the mechanics section of the syllabus using improvised equipment. If more in-service workshops were held with these teachers, chemistry components would also have been included in the original plan. This shortcoming was unavoidable as the number of workshops had to be curtailed due to the reasons given earlier in this chapter.

Except one teacher, all the others said that the hand-outs given were sufficiently clear and they commented that the contents increased their knowledge. The one who said that it was not clear could have been one of those teachers who did not get the first handout. Therefore, the additional hand-out given on this day would have been inadequate for him on that day of the workshop. The increase in the number of participants at this in-service workshop was unexpected, and extra copies of past handouts were not available that day.

To the question if improvisation was new to them, seven said that it was not new. One said, "I knew about it, but I wasn't then keen on doing it till now." This shows that they are now keen to do it. Some said that they had done some experiments involving improvisation in their teaching. The majority (15) said that this was indeed a novel experience for them. The fact that at least one teacher had used improvisation was encouraging. It is because of such teachers, perhaps, that some students have responded positively to certain questions in their questionnaire. They have said that they liked doing practical work and were interested in physical science.

Regarding the content covered by the in-service workshops, most teachers said that it was just right. However two said that it was too ambitious. Six said that it was too little 'because there are so many experiments in standard 10', according to one, and 'because I was still wanting to learn more about certain topics' according to another. The in-service workshop was neither meant to cover the entire syllabus, nor to enable the teachers to become familiar with all the experiments. The responses to this questionnaire, especially about their desire to attend further workshops of this nature, were quite revealing. All the teachers responded that they would like to attend more workshops. They identified areas like acids and bases in chemistry, experiment in chemistry with chemicals at home, organic chemistry, electrochemical cells, titration, electricity, all the laws of Newton, experiments with gases and pressure. To help the teachers in other aspects of improvisation and to continue the in-service workshops started in 1993/94, application for funding for four similar in-service workshops for 1995 has already been submitted to the FRD under the Science Education Research and Development programme proposal, titled "Teaching of Physical Science with the Aid of Improvised Equipment". Depending on the outcome of this application, it is hoped that similar in-service workshops can be held in 1995.

Except two teachers who mentioned that the in-service was average, all the others graded the in-service as good. Some wanted further workshops on other topics. All of them responded 'yes' to the question whether they would like to attend a formal course conducted by the University for the upgrading of teachers. This will provide them with better competency in the subject and the methods of teaching the subject. This generated much enthusiasm among teachers who wanted such a course started soon.

Many science teachers are keen to study further, both to improve their qualifications and their knowledge of the teaching of the subject. The qualification these teachers already have is unfortunately not sufficient for them to pursue further studies in the area of science and/or mathematics education though they have been teaching these subjects for several years. As a result, many such science/mathematics teachers are following part-time commerce or arts degree programmes at the University of Venda. Their degree work does not help them to become better science/mathematics teachers. If these teachers had had the opportunity to further their education in the field of science/mathematics education, they would have continued in that line and could have become better trained teachers in their subjects. Further education in this line would have been meaningful training to them. It would have helped them to be better teachers in the subjects that they are teaching. It would also have helped them to get further academic qualifications in the relevant subjects.

Question 14 in this questionnaire asked them if they would like to follow a formal course in the teaching of physical science/mathematics/biology at the University with the aim of obtaining a diploma or a certificate. All the teachers answered 'yes' to this question and some added that they would like it very much. One teacher commented that "...this is very important to develop our country in science and technology." Many teachers have followed this up by meeting the researcher subsequently and asking about the possibilities of such a diploma course. Having identified this need and the keen interest in such a course and the useful function it can serve the community, the Science and Mathematics Education Unit of the Faculty of Education has already initiated a proposal. According to this proposal, a course for teachers of science and mathematics should be started. This should be a part-time course over a one-year period at the University of Venda. This proposal has been accepted by the Faculty Board and is expected to get the necessary approval soon for its implementation in 1995.

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CHAPTER 6

SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSIONS

6.1 INTRODUCTION

Science teaching has been dominated by the transmission of facts, the 'tyranny of abstractions' and the clutter of 'inert ideas' (Whitehead 1932, as quoted in Wellington 1989: 8). We are all the time inundated with many facts. This is because of the 'information explosion' which has made the teaching of facts highly questionable (Wellington 1989: 9). Teachers are of the view that their students ought to know those facts. Is this possible? T. S. Elliot in *Choruses from the Rock* (Grayson 1992: 25) asks,

> Where is the wisdom we have lost in knowledge?
> Where is the knowledge we have lost in information?

What teachers have to do is to treat the students as thinkers. Students should be taught to think for themselves. They should be guided to "develop the ability to access, use and ultimately add to the information store when required" (Wellington 1989: 9). Students should be made to be learners. If we can achieve this goal, then teachers need not worry about teaching them **all** the facts; students will do the learning by themselves. The goal of teachers should be to impart wisdom. Information as knowledge must give the students the wisdom that will enable them to teach themselves. Louis Pasteur said that in the field of observation, chance favours only the prepared mind (Wellington 1989: ix). The wisdom given to students should prepare them to take advantage of their exposure to chance, to facts and to knowledge. A balanced science education should involve and bring about some sort of equilibrium between the content taught, the process involved and the context in which it is taught and applied.

Students studying science should be genuinely involved in scientific investigations. To bring out their full potential, students need encouragement, motivation, confidence, and commitment. Students can relate the content of what they learnt to their environment and make it meaningful. By such learning, they should construct their own knowledge. Knowledge cannot simply be transmitted. For the construction of knowledge, students should put in effort on their own, be motivated and work towards getting it. Are our science teachers helping our students to learn this way? Are the teachers sufficiently knowledgeable in their subject and methods of teaching? Can the method of simple passive transfer of subject matter from science textbooks help students to construct their own scientific knowledge? These are questions that can now be answered.

If students are to learn science meaningfully, use the process approach, understand what they learn, learn to teach themselves, construct their own knowledge, and fit in well as productive citizens of today, they should be taught science in such a way that they can achieve these aims. To enable this to happen, teachers need to **change** the way they teach. This research is concerned with the way teachers should be trained to bring about such changes. They should be able to teach their students science, using the process approach. This approach will enable the students to form their own wisdom from the scientific knowledge they were guided to acquire. They will do science projects and, in the process, relate new knowledge with the old, develop the right attitude towards science and be motivated to learn science on their own. Such learning by the doing of projects in science - even if simple ones - will help them learn many scientific facts by themselves. During their training - whether during preset or inset - teachers must also work on projects on their own or in small groups. Then they can help their students learn science by doing, experiencing and relating science to their environment. Thus, the teachers have the exposure and hands-on experience to guide their students to construct their own scientific knowledge using the process approach.

6.2 SUMMARY OF THE FINDINGS

Science teachers experience many problems in Venda. There are many teachers who are not adequately qualified in science to teach at the senior secondary level. The teachers who have done an education diploma course are not usually competent to teach science with understanding and insight, as a doing subject. "It cannot be doubted that a content-led approach with an overemphasis on inert knowledge, difficult abstractions and factual recall has failed" (Wellington 1989: 18). The content is not even taught in relation to the right context to give meaning to science. The process approach is not used in teaching science. Students are not provided with the opportunities to learn science content using the holistic approach and involving students in genuine scientific investigations (Wellington 1989: 3). They fail to appreciate the richness of the subject and to experience, first-hand, the applications and the usefulness of science in their daily lives.

These problems are caused by the shortcomings already mentioned in the report of the Commission of Inquiries into the System of Education in Operation in the Republic of Venda in July 1982. Some of them are minimum facilities for teaching science does not exist in the schools. The few facilities for teaching science are not used maximally in the few schools where they are available. This is partly because of the poor training of the teachers, partly because of the culture of teaching and learning which is textbook-centred and the lack of study skills and the tradition of rote-learning. The teacher-needs include revision of pre-service training and investment in in-service training. Teacher quality improvement, motivation and involvement in curriculum renewal and other professional activities require attention. (Report of the Commission of Inquiry into the System of Education in Operation in the Republic of Venda 1982: 58-66).

The existing science syllabus is also very ambitious. It is not formulated against the background of the pupils, the teachers, the schools, the available facilities and resources for teaching science in most schools. The needs of the students and the immediate community to which the students belong have not been taken into account in formulating the syllabus. Perhaps, there was, at the outset, not much involvement of the stakeholders and implementors in the formulation of the science curriculum. Due to these factors, science was only made available to a selected few. In the present context, science must be made accessible to more students. As discussed by Shayer ((1986), in Wellington 1989: 9), school science can be opened to a much wider range of ability by reducing its content and by making it less abstract.

6.2.1 ROLE OF IMPROVISATION IN THE TRAINING OF TEACHERS

The role of improvisation in training teachers was investigated under two headings: in the preset of teachers, and in the inset of teachers. The former is for those who are undergoing training to become teachers at either a college of education or through the teacher-education programmes of a university. The inset is for those teachers who are already teaching in schools with or without professional training or a degree. The effectiveness of teacher-training to cause changes in the teaching of science at the secondary school level was examined both at the preset and the inset levels in this research. The study of preset was restricted to the training of physical science teachers doing the University Education Diploma (UED) course at the University of Venda; that of inset was restricted to eight teachers from various schools selected from different educational areas in Venda. They participated in special inset workshops on improvisation in the teaching of physical science.

6.2.1.1 SUMMARY OF THE FINDINGS FROM THE USE OF IMPROVISATION IN THE PRESET OF STUDENT-TEACHERS

The use of improvisation by student-teachers helped them to learn many finer details in physical science by doing simple science projects during this course. Their attitude to teaching and learning changed. They appreciated the fact that science can be taught effectively by doing experiments in class. They learnt that many experiments can even be done without laboratories or science equipment. They were made to understand that they need not rely on science textbooks as the only source for science education. They were also able to find that there are several experiments that are simple enough to be done without the use of laboratory equipment. They found that doing experiments need not always be time-consuming or difficult.

The teacher-trainees learnt about improvisation by taking part in doing science projects on their own and presenting them to their peers. This method of independently working on projects and presenting them to their peers helped them to experience for themselves the advantages of **doing** science. They had opportunities to become aware of the applications of science to daily life. They learnt to make use of the resources in their homes and their immediate environment to do experiments. The trainees were exposed to the resource people in their environment to whom they could go for help to do their projects and obtain certain material for the projects. By doing their own projects this way, they developed their self-confidence. They also got the motivation this way to learn science by doing experiments. They learnt to make their own decisions in producing improvised equipment. The most useful learning experience for these teacher-trainees was the doing of their own projects with improvised equipment and the presenting of the projects to their peers. By doing these, they learnt to teach physical science the way it should be taught to their students in class. Having experienced the advantages during this training, they commented that this experience was the best part of their preparation as science teachers in this course. Their recommendation for improvement of the course was that more such opportunities for making their own improvised equipment and presenting them to their peers must be provided. Such training would enable them to become better physical science teachers who could make their own decisions and teach the subject meaningfully. They were sure that they could use this method in teaching physical science once they went out as fully-fledged physical science teachers.

6.2.1.2 SUMMARY OF THE FINDINGS FROM THE USE OF IMPROVISATION IN THE INSET OF TEACHERS

In training teachers, the use of gentle persuasion with discipline can help them to break away from the traditional rote-learning they were taught when they were at school. This can also help these teachers to use different methods that could cause better student learning of physical science. This is not possible with teachers who are already in service. The methods they use in teaching physical science that is not suitable today have to be first undone. New and useful methods of teaching can only then be introduced to them. It is common experience that old habits are difficult to transform. Further, the time span of exposure teachers have during such inset is limited because they are usually held only occasionally. Under such conditions, the teachers may not be able to effectively use the new methods when they return to their schools at the end of the in-service training. Further, there is usually very little or no follow-up to in-service training given to teachers. In addition, the teachers are normally burdened with much work at school. They have little free time and are expected to prepare their lessons, mark class work and tests and teach more than one subject in more than one standard and their classes usually have large numbers of students. Under such conditions, it is unreasonable to expect them to follow meticulously the new methods of teaching following in-service training. In-service training will be more effective if it is held more frequently and regularly. There should also be follow-up workshops and other forms of training participants to ensure the monitoring of their progress as regards the implementation of the new approach. Further, the inset should be designed bearing in mind the preset described previously. The participants are involved in doing and teaching their peers as they would in the class. Such teaching generates the enthusiasm in the participants, and they feel free to comment on the projects and the teaching. They learn by exposure. This is obviously a better way of teaching physical science.

The teachers who underwent inset as part of this research have shown a significant change in attitude. This is borne out by the summary of their responses to the questionnaires given to them before and after the in-service workshops. The informal discussions held with these teachers and their responses to the end of inset questionnaires have also been useful to know the changes these teachers have undergone as a result of the inset workshops.

Evidently there are several teachers who need help both in the content and methodology of teaching physical science. Those who attended the workshops realised that textbooks need not necessarily restrict the scope of the science lessons. There is no need to complain of the lack of facilities for practical work, and do nothing about it. They realised that several experiments could be done in physical science using improvised equipment. They also realised that by *doing* science experiments, they could *understand* science better and this would enable them to make the subject *interesting* to the students. This method also helps to relate the subject to the *environmen*t where many aspects of science are used in various ways. Such relationship of science content to the context in which it is used helps the teachers to realise the need for the *mastery of the processes* involved in doing science. This could help them to think and function as scientists. This exposure has made these teachers use these methods in their teaching in their schools. This has helped in better student learning as seen from the responses received for the student attitude questionnaires.

Providing teachers and teacher-trainees opportunities to work on projects, presenting them to their peers and allowing them to be critical in making their comments on the presentations of their peers can help them to note and use the good points observed during the presentations. This can also help them to see their own mistakes in their assumptions, experiments and explanations. This will help them to avoid such shortcomings in their classroom teaching.

The greatest advantage in using the method of improvisation in teaching physical science is that this method can be readily available in teaching the subject in any school in South Africa, even if the school has no science equipment or science laboratory. The change in the approach to teaching physical science will encourage students to be interested in this subject. It will help them learn science with enthusiasm and a desire to succeed and excel in it. It will, in turn, bring out hidden potentials for doing and applying science, which will help students throughout their lives, whether they go for further education or not.

6.2.2 STUDENT BENEFIT BY THE USE OF IMPROVISATION IN THE TEACHING OF PHYSICAL SCIENCE

The advantages of the use of improvised apparatus in teaching physical science have been attested from the analysis of the responses to the two questionnaires given to the students before and after the workshops in the use of improvisation.
The students show a change in their attitude in the following ways, as a result of the use of this method of teaching physical science:

1. They realise the importance of doing practical work in physical science to understand science concepts and become familiar with the processes of science.
2. They show interest in doing their own projects in physical science. This will help them to bring out their hidden talents in applying their science knowledge to doing science, and in the use of other psychomotor skills.
3. By being involved in doing projects, they learn to use the processes of science. Such processes are applied to real situations. The application will

give them the necessary training, connoisseurship and craft skills in the use of the scientific method. This will be advantageous to the students, whether they leave school or continue with further education. They would have used and mastered at least some basic scientific processes at school that they can now apply to real life situations at any time.

4. Understanding processes in science makes for better learning, because science is a doing subject and knowing some science processes will help the students to use them in real life situations in solving problems. This can help them in their jobs or be useful in further education in the field of science.

5. Learning science by doing experiments creates interest in the subject; therefore, students are motivated to learn and excel in this subject.

6. They accept that to do experiments, one need not be working in the laboratory. Therefore, they are encouraged to try out many experiments at home on their own. They learn and understand science by doing experiments using the process approach. This approach enables them to work on their own, and in so doing, they construct their own knowledge.

7. They develop a positive attitude towards physical science, start developing confidence in themselves and learn even if they make mistakes by applying the scientific method; in this way they start functioning as budding scientists.

8. The students are helped to move away from the textbook-dominated traditional method of learning physical science to an explorative and investigative method. The use of such a method develops positive and acceptable social attitudes that will help them to fit harmoniously in their society in the real world.

9. This method helps to break the teacher-dominated teaching cycle. It encourages student-centred learning. It results in better student-teacher interaction, which has been prominent by its absence in most schools in

Venda. This change is essential to make science an interesting and attractive school subject.

10. These changes will enable the students to come out of the straight jacket of mediocrity cycle and cause properly educated scientists in this country.

6.2.3 THE NEED TO MASTER THE PROCESSES IN SCIENCE

It cannot be doubted that a content-led approach with an overemphasis on inert knowledge, difficult abstractions and factual recall has failed (Wellington 1989: 18) as far as science education is concerned. This is particularly true of science education in South Africa. The process approach more actively involves the students in science education. This should be a welcome change to the traditional method of teaching physical science from textbooks in the schools in Venda. Learning should result from an interaction between new situations and the present knowledge. In order for meaningful learning to take place, the student must relate that which is to be learnt to the mental models that he already has. Therefore, learning must be an active process. Science needs the use of a variety of skills and processes. These psychomotor skills must be mastered by science students and teachers alike. Doing experiments helps the students to develop their psychomotor skills and their attitudes besides the understanding of the science content.

Students learn these skills and develop the attitudes by actually doing scientific investigations in their physical science lessons. They first do simple experiments, but the experiments are complete investigations. As they get confidence and experience in doing experiments, their investigations become more complex and sophisticated. Those teachers with experience in the use of investigations in their teaching of physical science remember the enormous improvement in the students' investigative techniques from their first attempt to their second - an improvement based partly on the students' learning from their own and their peers' experience and partly from the teachers' learning from theirs (Wellington 1989: 121).

Students learn to use investigative techniques that are important for science. The use of these techniques helps them to become better in their investigations. It also gives them the necessary confidence to do more. Having done experiments that are worthwhile, they are encouraged to do more intricate investigations. After such experience, they do not hesitate to learn science by doing and improving the process of doing experiments on their own. This should be the aim of science education. It helps to change the approach to learning of science from simple acceptance of facts told by the teacher, or found in the books, to doing their own learning by probing, investigating and following scientific principles and procedures to achieve the learning objectives.

6.2.4 TEACHERS' ABILITY TO CONSTRUCT IMPROVISED EQUIPMENT

Teachers who are exposed to constructing their own improvised equipment turn out equipment that is either good or poor depending on their flair for doing things with their hands. However, because of their continued effort to try to make more equipment, and because of the comments made by other teachers (and perhaps the students), they improve their ability to turn out better apparatus, after their first attempt. To grow in their profession, teachers need to have opportunities to come together to discuss such issues that can help them to improve their science content and ability. They should be involved in the implementation of the process approach to the teaching of science and share their experiences in the construction and use of improvised apparatus. Subject associations, in-service workshops, project week, exhibitions, science fairs and holding of competitions, like Expo for young scientists, could enormously help teachers to develop their confidence in doing and improving their ability to do projects. It helps them to learn science as a doing subject in their schools and helps their student to learn physical science better.

6.2.5 APPLICATION OF SCIENCE TO REAL LIFE SITUATIONS

Improvisation helps students and the teacher to see science in relation to their environment and the society in which they live because of the following:

1. The materials for improvisation comes from the immediate environment of the students and teachers.
2. The students and teachers, in finding the material for improvisation, are exposed to places and occasions where science is applied in real life situations.
3. The student or teacher meets people in his environment who are competent in certain aspects of science with which they are involved in working for their livelihood.
4. Students and teachers see the various applications of science in their environment.
5. Students and teachers learn to be innovative and are ready to apply their knowledge of science in the class, at home and elsewhere whenever an opportunity for its application arises.
6. Students come to know various vocations related to the study of physical science.
7. Science becomes a meaningful and interesting subject to both the teacher and the student.
8 The student and teacher learn, by doing, the principles and methods involved in scientific endeavours and learn to make their own decisions about a problem or a task based on scientific facts.
9. The student or teacher learns science 'discipline' in using the process approach to learning science.

6.2.6 TEACHER-STUDENT INTERACTIONS DUE TO IMPROVISATION

The use of improvisation in class will result in learning which results from a two-way communication and interaction between the teacher and the students. It will help in bringing better dialogue between the students and the teacher. The learning takes place because of informal communication between the students and their teacher outside the classroom and cause interest in science. Learning becomes a joint venture in which both the students and the teacher jointly play active roles. Such learning helps the students to internalise the principles, methods and processes involved in science. Such active learning is an exploratory experience from which both the teacher and the students benefit enormously. Such learning will be a pleasant and active experience to the students. They construct their own knowledge that they can always make use of in any situation in life.

6.3 RECOMMENDATIONS BASED ON THE FINDINGS

Based on the findings of this study, the following recommendations can be made about the teaching of physical science, especially in Venda. These recommendations are equally applicable to other areas where the conditions for science education are similar to those in Venda and the teachers are in need of training as in Venda. This will help them improve both their methods of teaching and their knowledge of the contents of physical science.

During teacher-training, especially at the preset, teacher-trainees need to be given the hands-on experience of teaching science by doing, demonstrating, involving the students in science projects and in doing the experiments in class by using improvised equipment. It is not sufficient for the lecturer to TELL or INFORM the teacher-trainees what to do, what not to do, how to improvise equipment, how to use them in class for effective teaching, where to go for help to obtain material for improvisation, or how best to improve the improvised equipment to make them work in the teaching of physical science.

What is needed is for the lecturers to teach the teacher-trainees the same way the trainees are expected to teach their science students. The lecturer needs to be involved in doing, demonstrating, involving the teacher-trainees and guiding them to construct their own knowledge from exposure and experience. The teacher-trainees need to be involved in projects on improvisation,individually or in small groups. They should present their experiments using the improvised equipment and teach their peers the science involved in the experiments they present. Peers need to learn to play the role of students in school, ask questions and interact as students would in a real classroom. Coming down to the level of students and thinking as students would is difficult. This is very essential for the success of a science teacher.

Having taught science this way, they must be given time to give their impressions of the lesson and project in a brainstorming session where the trainees should be free to express their individual views on the following: the project, its strengths, how it could have been improved or modified to work better; if the teaching was clear enough to enable them understand the teaching and any improvement necessary in the teaching or the project presented in class. All aspects of teaching may be touched upon in these discussions. It is better to carry out this programme early in the training of teachers, so that they do not acquire unwelcome habits, and have a chance to start with proper acceptable and useful habits and methods of teaching physical science by the time they go out for their practice teaching in the schools.

Concerning teachers in service, regularly conducted in-service courses on similar lines as for the teacher-trainees need to be encouraged. This may not be as rigorous as for preset for obvious reasons. Regular in-service courses will ensure that teachers' learning of new methods and contents will remain sufficiently up-to-date and fresh in their minds and become part of their thinking. This will make them feel comfortable to use them in their teaching. Regular meetings on a more informal level with other teachers to share ideas can help tremendously to improve their lot. This can happen, as mentioned previously, through such structures and activities as subject associations, seminars, workshops, science fairs, Expo competitions, publications of science magazines and bulletins.

Starting diploma courses in different science disciplines to help those teachers who need assistance in upgrading their qualifications and paving a path to further their education in their chosen field of science education is essential. This will help them to be not only qualified and eligible for promotions, but also **knowledgeable** in their subject and methods, so that they could teach with confidence. This is important to uplift the standard of science education.

Teachers must be exposed to the science equipment that are normally available in schools. They should be familiar with the use of the equipment in a classroom situation so that they could use them with confidence and safety in teaching science by doing, whenever equipment is available. This should be done during inset for the teachers in service and during preset for prospective science teachers at both the colleges of education and the universities.

Teacher-training must include improvisation as a component in order to enable the teachers to use it in their teaching. This training should be in a manner that achieves those objectives that were discussed under recommendations. Such training will help **all science teachers** in their teaching career, and will result in the production of the much-wanted teacher-technicians who can teach science to fit students into the real world. Such teachers can no doubt teach better, if equipment and laboratories are available in their schools. This training will therefore result in better teachers who can teach physical science in a meaningful manner now and in the future in any school situation.

6.4 CONCLUSIONS

Science education should enable the students to fit in the society. It should enable them to make judicious judgements in the modern world, where science and technology play such vital roles in shaping our lives and our future. To help students achieve this aim, science should be taught so that its various facets are made clear to the students. In order to do this, science teachers need to be educated or re-educated as the case may be. They should see science not as a body of inert ideas that have to be transferred to the students from the textbooks, but as a dynamic subject that involves knowing and understanding, exploring and discovering, imagining and creating, feeling and valuing, and using and applying so that the total richness of science can be experienced and appreciated by all students doing science. This will result in the students attaining the level of scientific literacy demanded by the society of today and the needs of tomorrow (McCormack & Yager 1989: 47).

The problem raised as the main issue in the first chapter can now be answered adequately in the affirmative:

> **Improvisation can be used as a strategy for the teaching of physical science so as to encourage the overall learning of the subject and eliminate the ill-effects caused by the lack of facilities for doing practical work in the teaching of physical science in schools in Venda.**

Whatever modern methods are used for teaching science, it is important, as Einstein described his own education, to make sure that the new methods will help the young student to learn science with an open mind and not restrict the individual's freedom:

> It is in fact, nothing short of a miracle that the modern methods of instruction have not yet entirely strangled the holy curiosity of inquiry, for this delicate little plant, aside from stimulation, stands mainly in need of freedom; without this it goes to wrack and ruin without fail (Wellington 1989: 133).

The use of improvisation as a strategy for the teaching of physical science in schools has all the necessary ingredients to encourage and nurture the enquiry spirit of curiosity. It provides the much-needed freedom for our students to learn science in our schools. This method can be used effectively to train teachers so that they give the students the necessary guidance to learn physical science with interest to meet the needs and the expectations of the modern scientific society and the technological world of tomorrow.

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APPENDIX I

MATERIALS FOR IMPROVISATION

Materials needed for producing improvised apparatus are many and varied. It is not possible to give a complete list of such materials. More materials are coming out daily that could be added to this list. The following list is just a sample collection from various sources for a start for teachers making their own improvised apparatus: (Source: UNESCO 1960: 14-18 and Farmer & Farrell 1980: 289.)

FROM THE HOME

Aluminium baking foils	Aluminium drink cans
Aluminium milk bottle caps	Aluminium pans
Basins	Bottles (various sizes)
Candles	Clock
Cloth peg	Cloth pins
Cloth, various kinds	Coke bottle
Colouring food	Combs, plastic and metal
Cork, dinner table mats	Cork, wine bottle
Cups and saucers	Dinner plates
Dishes	Dye
Flower pots	Flowers
Fruit Jars	Garden tools
Glass tumbler	Hand gloves
Hand tools	Hangers, wire
Ink bottle	Inks
Jam tins	Jars
Knives	Leather, from old shoes
Lemon	Matches
Milk cartons, bottles	Mirrors
Musical instruments	Nail polish remover
Nail varnish	Needles, sewing, knitting
Oil, can	Old electric appliances
Pans, old	Paper bags
Paper clips	Paraffin
Pencil, lead	Pens
Pins	Plastic drinking cup
Plastic bags	Razor blades
Rubber mat	Ruler
Salt	Salt shaker
Soap	Spools, wooden/plastic
Spoon	Sugar
Sweet wrappers	Tea
Tin cans	Tissue
Toilet roll	Tooth brush/tooth paste used tubes

Twine
Vinegar
Used electric bulbs
Zip

FROM THE HARDWARE SHOP

Asbestos sheet/thread
Battery jars
Bolts and nuts
Candles
Compass
Corks
Curtain rod/railing/rings
Forceps
Funnels, Metal/plastic
Glass, sheet-plane
Hack-saw blade
Hooks, assorted
Lamp chimneys
Insulating material
Marbles, various
Mirrors
Needle, various
Paint
Plywood
Sand paper
Scissors
Screw eyes
Shears
Spikes, assorted
Steel wool
Tape measures
Thermos flasks
Varnish
Wash-tub
Wood blocks/prisms
Balls - metal/wood
Block and tackle
Brick
Cement
Copper wire
Cup, tin/aluminium
Egg beater
Flash light/bulb/battery
Glass jars
Glue
Hand-cleaner
Lamp black
Lime
Magnets
Metal rods/sheets
Nails, various
Oil & oil cans
Plumb line
Press board
Saw dust
Screw driver
Screws
Sieve
Springs
Tacks, thumb/carpet
Thermometers
Tools
Washers
window glass

FROM THE AUTO SHOP

Ammeter
Battery acid
Coils
Curved reflector from headlights
Distilled water
Electric bulb
Electric motor
Ball bearing
Brass/copper rod/sheet
Curved mirrors
Cut-outs
Electric alternator
Electric generator
Electric water pump

Electric wiper motor
Fuel pump
Fuses
Gears
Headlight lens/bulbs
Ignition coils
Iron rods/filings
Iron sheets
Lead
Magnet from speedometer
Oil (used)
Rubber tyres/tubes/valves(old)
Scrap metal pieces
Solenoid
Spark plugs
Springs from seat
Storage batteries
Sulphuric acid
Tools

FROM THE RADIO REPAIR SHOP

Ammeter
Amplifiers
Coils
Condensers
Electrical instruments
Electrical wires/elements
LCD
Magnet from old speaker
Metal plates
Old radio valves/diodes/resistors
Plastic from old cabinets
Radio sets
Rheostats
Solder
Transformer/core
Wires from old coils

FROM THE SUPERMARKET

Ammonia
Baking powder
Bleaching powder/solution
Bees wax
Blue powder
Boards from boxes
Boxes, cardboard
Citric acid
Coloured chalks
Cooking oil
Corn syrup
Cotton cloth
Cotton thread
Dyes
Electrical toys
Electric wires
Epsom salt
Football pump adaptors
Gelatine
Glue
Gyroscope
Lard
Linen cloth
Linen thread
Matches
Marbles
Mechanical toys
Methylated spirit
Mineral oil
Paper bags
Ping pong balls
Plastic toys
Rubber balloons
Rubber balls
Sealing wax
Seeds
Silk cloth
Silk thread
Snooker balls
Starch
Steam engine
Steam turbine
Strings
Sugar

Synthetic fabrics
Table tennis balls
Thinner
Turpentine
Woolen cloth
Table salt
Tartaric acid
Toy musical instruments
Vinegar

FROM THE PHARMACY

Adhesive tapes
Boric acid
Copper sulphate
First aid kits
Glass tubes
Hydrogen peroxide
Iodine
Manganese dioxide
Medicine bottles
Medicine vials
Peptones
Potassium chlorate
Rubber/plastic tubes
Saccharine
Sheet rubber
Sodium bicarbonate
Sodium hydroxide
Thermometers
Agar
Cellophane
Dyes
Funnels
Hydrochloric acid
Ink
Litmus paper
Marble chips
Medice dropper
Mineral oil
Plaster of paris
Powdered sulphur
Rubber stoppers
Shaving mirrors
Silver nitrate
Sodium carbonate
Sponges
Wood tongue depressors

FROM THE ELECTRIC SHOP

Batteries, dry
Electric bulbs
Electric meters
Insulated wire
Lamp sockets
Miniature light socket
Push buttons
Electric bells
Electric buzzers
Heating elements
Insulation tape
Magnetic compass
Old electric appliances
Switches

FROM THE BICYCLE REPAIR SHOP

Ball bearings
Bicycle pump
Rubber grips and handle bars
Sprocket wheel
Valves from tubes
Bicycle lamp
Inner cycle tubes
Spokes from bicycle wheels
Used bicycle wheels
Wheel axles

FROM THE SCHOOL

Blotters	Burnt-out electric bulbs
Cardboard	Chalk
Chalk boxes	Coloured chalk
Erasers	Fluroscent tubes
Fuses	Globes
Gummed labels	Ink
Maps	Oil
Paper	Paper clips
Paper-towels	Pencils
Rubber bands	Rulers

COLLECTION OF SOME USABLE "JUNKS"

Bags and baggies (plastic)	Bags: assorted sizes (paper)
Balloons	Balls
Batteries	Battery charger
Bolts and nuts	Bottles(galss & plastc)
Boxes (Cardboard, plastic, wood)	Candles
Cans	Cardboard
Cards (index)	Cartons (milk, tissue)
Cigar boxes	Cigarette tins
Clay	Cloth
Clothespins (pinch)	Corks
Cotton	Dishpans (plastic)
Dowels	Eye droppers
Fishline	Fish net sinkers
Flashlight bulbs	Flower pots
Foils(aluminium, plastic)	Funnels
Glass (flat pieces)	Globe (models of earth)
Household chemicals like alcohol, etc.	Inner tubes
Jars (screw top glass)	Lead shots
Magnetic iron ore (lodestone)	Magnets
Magnifying glasses	Marbles
Mirrors(plane, curves)	Nails
Old clock springs	Old roller skates
Old watch spring	Pails/buckets
Pantihose	Paper clips
Paper (construction, wax)	Pins (common, safety)
Pipe cleaners	Polystyrine
Razor blade (single edge)	Ropes
Rulers	Saw dust
Screws	Seeds

Soda straws
Springs
Strainers (kitchen)
Tape (electrician's, masking, transparent)
Telephone receivers
Tennis balls
Threads
Tools
Tumblers (glass, plastic)
Wires
Soil (sand, loam)
Stoppers(Rubber)
String
Telephone magnets
Telephone transmitters
Thermometers
Tin and aluminium foils
Tubes (cardboard, metal, rubber)
Washers (metal, rubber)
Wood

SIMPLE TOOLS FOR CONSTRUCTING SIMPLE EQUIPMENTS

Brace and bits
Cloth shears
Electric drills and drill bits
Electric saw and blades
G-clamp
Glass cutter
Hammers
Leather punch
Metre stick
Paring knife
Pliers
Round file
Screw drivers
Small table vice
Solder and soldering iron
Stapler
Triangle file
Wrenches
Can opener
Coping saw
Electric grinders(cricular)
Flat file
Gimlet
Hack saw/metal saw
Jack knife
Metal shears
Multimeter (electronic)
Piece of heavy bench iron
Polystyrine Cutter(electric)
Sand paper
Small block (plane)
Small wood saw
Sprit level
steel wool
Wood chisel

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APPENDIX II

STUDENT-TEACHER ATTITUDE QUESTIONNAIRE (ST-QR)

NOTE:

* This questionnaire is part of a study concerning the teaching of physical science in schools in Venda.
* The aim of this study is to help teachers improve their effectiveness as physical science teachers.
* Your responses to this questionnaire will be treated confidentially. (You are not required to write your name on the answer sheet of this questionnaire.)
* Please feel free to give your honest and frank response to the statement in this questionnaire.

INSTRUCTIONS:

THE RESPONSE TO THE FOLLOWING STATEMENTS SHOULD BE MADE ON THE SPECIAL ANSWER SHEET BY PLACING A CROSS IN ONE OF THE RELEVANT COLUMNS AS TO YOUR DEGREE OF AGREEMENT TO THE STATEMENT

1. Physical science is my favourite subject.

2. The best way to teach physical science is to follow closely the recommended textbook.

3. The experiments in physical science can only be done satisfactorily in a properly-equipped school laboratory.

4. The teaching time allocated to physical science will not permit a teacher to do practical work in teaching physical science.

5. Some practical work in physical science is simple enough to be done easily in the classroom.

6. I will not do practical work in class, as there is no point in doing some of the simpler experiments leaving out the more difficult ones.

7. I will do as many experiments as possible in physical science in class, if I am posted to a school that has science equipment.

8. If I am to do practical work in physical science in class satisfactorily, I need to be trained in the use of the apparatus found in a school laboratory.

9. Students benefit in their learning of physical science even if only few practicals are done in class.

10. The extra effort and energy spent in doing practical work in physical science in class is not worth it.

11. As it is expensive to do practical work in a science class, it is not worth doing practical work in teaching physical science.

12. Teacher demonstration experiments in class are not helpful in teaching physical science.

13. Students who have access to textbooks understand physical science, even if they do not do any practical work in class.

14. Practicals are not useful in teaching physical science in class, as the answers obtained are usually not accurate.

15. The time wasted by a physical science teacher in preparing to do practical work in class could be profitably used by the teacher to teach the syllabus.

16. Experiments done in class are only useful if they give accurate and convincing results as in the textbook.

17. I hate to think of doing practical work in class, as so many things could go wrong in class while I am in front of the students.

18. Physical science must be taught by doing practical work in class, for effective learning of the subject.

19. As a student, I did not do any practical work and so I do not see any point, when I start teaching, in forcing my students to do practical work in physical science in class.

20. Importance need not be given to practical work in class in the teaching of physical science.

THANK YOU FOR YOUR CO-OPERATION

=KSR=================================9=2=94=

APPENDIX III

SUMMARY OF STUDENT-TEACHER RESPONSES (START, ST-QR-C)

No:	STRONGLY AGREE			AGREE			DISAGREE			STRONGLY DISAGREE		
	M	F	M+F	M	F	M+F	M	F	M+F	M	F	M+F
1	8	2	10	1	2	3	1	0	1	0	0	0
2	0	0	0	5	0	5	3	2	5	2	2	4
3	4	1	5	4	3	7	2	0	2	0	0	0
4	2	0	2	4	1	5	3	3	6	1	0	1
5	5	0	5	4	3	7	1	1	2	0	0	0
6	0	1	1	1	0	1	1	2	3	8	0	8
7	2	1	3	5	2	7	1	0	1	1	0	1
8	3	1	4	3	1	4	2	1	3	1	0	1
9	0	1	1	4	1	5	4	1	5	2	1	3
10	0	1	1	3	0	3	2	1	3	5	2	7
11	0	0	0	0	0	0	2	2	4	8	2	10
12	1	0	1	0	0	0	2	2	4	7	2	9
13	0	0	0	4	2	6	6	1	7	0	1	1
14	0	0	0	0	0	0	5	3	8	5	1	6
15	1	0	1	1	0	1	3	1	4	5	3	8
16	2	0	2	2	0	2	3	2	5	3	2	5
17	0	0	0	1	0	1	5	3	8	4	1	5
18	5	1	6	3	2	5	0	1	1	1	0	1
19	0	0	0	0	0	0	1	1	2	8	3	11
20	0	0	0	1	0	1	4	4	8	5	0	5

APPENDIX IV

SUMMARY OF STUDENT-TEACHER RESPONSES (END, ST-QR-E)

No:	STRONGLY AGREE			AGREE			DISAGREE			STRONGLY DISAGREE		
	M	F	M+F	M	F	M+F	M	F	M+F	M	F	M+F
1	5	3	8	4	2	6	0	0	0	0	0	0
2	0	0	0	0	0	0	7	2	9	2	3	5
3	2	0	2	1	1	2	5	4	9	1	0	1
4	1	1	2	3	2	5	4	1	5	1	1	2
5	8	3	11	1	2	3	0	0	0	0	0	0
6	1	0	1	0	0	0	0	4	4	8	1	9
7	3	0	3	4	2	6	0	2	2	2	1	3
8	1	0	1	3	3	6	2	1	3	3	1	4
9	2	0	2	4	3	7	2	3	5	0	0	0
10	0	0	0	0	0	0	2	2	4	7	3	10
11	1	0	1	0	0	0	0	2	2	8	3	11
12	1	0	1	0	0	0	3	2	5	5	3	8
13	1	0	1	4	0	4	3	4	7	1	1	2
14	0	0	0	1	0	1	3	3	6	5	2	7
15	0	0	0	1	2	3	5	1	6	3	2	5
16	1	0	1	2	0	2	2	4	6	4	1	5
17	0	0	0	1	0	1	3	3	6	6	1	7
18	4	1	5	4	3	7	1	1	2	0	0	0
19	0	1	1	0	0	0	1	1	2	8	3	11
20	0	0	0	1	1	2	5	2	7	2	2	4

APPENDIX V

FACULTY OF EDUCATION

The Director General of Education
Department of education
Sibasa
Venda

Dear Sir

USE OF IMPROVISED APPARATUS IN TEACHING SCIENCE IN SCHOOLS

I am happy to inform you that I have obtained a grant from the Research and Publications Committee of the University of Venda to make a modest start in introducing the idea of improvised apparatus as a means of improving the effective teaching of physical science in schools in Venda specially in selected schools with no laboratory facilities and not well qualified teachers of this subject.

The period of this project will be from 10th May 1993 to about the end of April 1994.

The number of schools to be involved will be ten. However, it is my intention to involve initially about 15 schools, so that if there are any that are not suitable or interested in this project as we go on, we could still have about ten schools to continue with this project.

The schools will be secondary schools doing standards 8 and 9. Standard 10 students and teachers are not involved in this for several reasons. Mainly, because they are exam going students and also because they will not be available for our continued use next year till April.

The schools could be urban and or rural. It is preferable to select schools where the teachers are not well trained in teaching science as they need the most help in improving the teaching of physical science. It is envisaged that one teacher teaching standard 8 and/or standard 9 will be selected for this programme from each school.

The project will involve the following:

1. Questionnaires and or tests given to students before, during and towards the end of the project.
2. Questionnaires given to teachers.
3. Inservice courses conducted with the teachers in which basically they will be exposed to the use of improvised apparatus and their use in teaching science meaningfully in class, constructing their own apparatus to teach science as a doing subject, use of these in class teaching at school.
4. Visits to schools to help with the teaching of science with the help of the apparatus made from simple equipment.
5. Some teaching in class to help teachers in bringing in this innovation smoothly.

The teachers will be paid travelling only from school to the University for taking part in the workshop sessions.

UNIVERSITY OF VENDA
PRIVATE BAG X2220, SIBASA • REPUBLIC OF VENDA • SOUTHERN AFRICA
TELEPHONE (015581) 21071-9/21080 • TELEFAX 22045 • TELEX 331694

The teachers will be supplied with improvised equipments to be kept and used in their schools to the value of not less than R150,00 per participating school.

Stationery for tests, questionnaires etc will be supplied.

The time of inservice workshops will be determined after discussions with the staff involved in the project.

The venue will be the Science Methodology Laboratory at the University of Venda for the inservice workshops.

I annex herewith a copy of the proposed programme of research for your further information.

There is a great need for improving science education in Venda. This project, will certainly help to improve science teaching specially in the disadvantaged schools of Venda. This will help to improve science education in venda and make the subject attractive for more students to offer in time to come.

As such I hope you will give your blessings for the implementation of this project this year starting in May.

If you need any further clarification on this project, my co-worker Mr. A. M. Tshavhungwe and or self will be happy to answer further queries on hearing from you.

I hope you will respond to this request without delay so as to enable us to start this valuable project as planned.

Thanking you. Hoping to hear from you soon.

Yours faithfully

K. Siresatarajah
Lecturer-Science Methodology.
21.04.93

APPENDIX VI

VP. 18

REPUBLIC OF VENDA

REPUBLIEK VAN VENDA

RIPHABULIKI YA VENDA

MUHASHO WA PFUNZO NA MVELELE
DEPARTMENT OF EDUCATION AND CULTURE
DEPARTEMENT VAN ONDERWYS EN KULTUUR

PRIVATE BAG
Privaatsak x 2250
SIBASA
Venda

Diresi ya thelegrafu
Telegraphic address *"PFUNZO"*
Telegrafiese adres

Nomborondaula
Reference No: 8/3/3
Verwysings nr.:

Hu vhudziswa: SUBJECT ADVISORY
Enquiries:
Navrae:

30 JUN 1993

Tel. No. (015581) 3-1001
Fax No. (015581) 3-1179

Mr. K. Siresatarajah
University of Venda
Private Bag X 2220
SIBASA
VENDA

Dear Sir

USE OF IMPROVISED APPARATUS IN TEACHING SCIENCE IN SCHOOLS.

1. The above matter refers.

2. I have pleasure to inform you that your proposal has been approved.

DIRECTOR GENERAL FOR EDUCATION AND CULTURE
/asd

APPENDIX VII

FACULTY OF EDUCATION

MY NO: MEM/WS/01 of 20 Sept 1993

MEMRANDUM

To: The Principal

.... school

P. O. Box ......

....

....

From: Sirestarajah. K
Faculty of Education
University of Venda
P. Bag X5050
THOHOYANDOU
Venda

Sir

IN-SERVICE WORKSHOP FOR PHYSICAL SCIENCE TEACHERS - 1993-94

I am happy to inform you that your school is one of the two schools in your area that has been selected to take part in a series of workshops for the physical science teachers to help improve the teaching of this subject in Venda. This programme will involve the following:

1. Workshop sessions lasting approximately three hours each with the physical science teachers on the following dates:
   1.1 13 October 1993 - Registration, and first workshop
   2.2 20 October 1993 - Second workshop
   2.3 26 January 1994 - Third workshop
   2.4 09 February 1994 - Final workshop

2. Starting time of workshop: 09h00 each day.

3. Venue: Physical Science Methodology Laboratory (next to the Music Department caravans) labelled EDU 2 in the old science block.

4. Travelling expenses will be paid to the participants.

5. The participating teachers will be expected to implement the programme in teaching physical science in their schools.

6. Only teachers teaching std 8 and/or 9 will be involved in these workshops so as to have continuity with the students in std 9 and 10 in 1994.

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7. Please be good enough to arrange the 1994 time table for the teachers taking part in these workshops so that these teachers teach physical science in the next higher class in 1994. This is to enable them to have continuity with the classes they teach and to ensure proper implementation of this project. (Eg: If the teacher is teaching std 8 physical science in 1993 then he/she will be teaching std 9 in 1994. Similarly a teacher teaching std 9 this year will be teaching std 10 physical science next year.)

8. If there are two teachers teaching these classes in your school, then either both of them or any one of them, according to your wish, could attend these workshops.

9. The schools taking part in this programme will be elegible to receive a set of 'home made' equipment that will be used to implement this programme in your school and for future teaching of physical science.

10. This programme is specially meant for those schools with no laboratory facilities or science equipments. The workshops are meant t benefit those science teachers who are genuinely in need of help to improve their physical science teaching in your school.

If there are any further queries please feel free to contact me at the following telephone number:

(0159) 21071 Ext 2218 (work) OR (0159) 31348 (home). Please note that my office is next to EDU 2 laboratory and not in the education faculty floor.

Please be good enough to supply me the name/s of the teacher/s and their particulars by filling the annexed form (WS/01/REP).

Please be good enough to circulate this letter to the teachers concernec and inform them about the dates of the workshops and release them from school to enable them to attend the workshops.

The first workshop will commence on Wednesday 13 October 1993 at 09h00 i the physical science methodology laboratory of the University of Venda.

Thanking you.

Yours faithfully

K. Sirestarajah
Lecturer-Science Methodology
20 September 1993

APPENDIX VIII

TEACHER ATTITUDE QUESTIONNAIRE (T-QR)

NOTE:

* This questionnaire is part of a study concerning the teaching of physical science in schools in Venda.
* The aim of this study is to help teachers improve their effectiveness as physical science teachers.
* Your responses to this questionnaire will be treated confidentially. (You are not required to write your name on the answer sheet of this questionnaire.)
* Please feel free to give your honest and frank response to the statement in this questionnaire.

INSTRUCTIONS:

THE RESPONSE TO THE FOLLOWING STATEMENTS SHOULD BE MADE ON THE SPECIAL ANSWER SHEET BY PLACING A CROSS IN ONE OF THE RELEVANT COLUMNS AS TO YOUR DEGREE OF AGREEMENT TO THE STATEMENT

1. I enjoy teaching physical science.

2. The best way to teach physical science is to follow closely the recommended textbook.

3. The experiments in physical science can only be done satisfactorily in a properly-equipped school laboratory.

4. The teaching time allocated for physical science will not permit a teacher to do practical work in teaching physical science.

5. Some practicals in physical science are simple enough to be done easily in the classroom.

6. I do not do practicals in class, as there is no point in doing some of the simpler experiments leaving out the difficult ones.

7. I would have done as many experiments as possible in physical science in class, had my school had the science equipment.

8. I would have done some experiements in physical science, had I known how to set up the apparatus in the laboratory to do those experiments.

9. Students benefit in their learning physical science even if only few practicals are done in class.

10. The extra energy and effort spent in doing practicals in physical science in class is not worth it.

11. As it is expensive to do practicals in a science class,it is not worth doing practical work in teaching physical science.

12. Teacher demonstration experiments in class are not helpful in teaching physical science.

13. Students who have access to textbooks understand physical science, even if they do not do any practicals in class.

14. Practicals are not useful in teaching physical science in class, as the answers obtained are usually not accurate.

15. The time wasted by a physical science teacher in preparing to do practicals in class could be profitably used by the teacher to teach the syllabus.

16. Experiments done in class are only useful if they give accurate and convincing results as in the textbook.

17. I hate to do practicals in class, as so many things could go wrong in class while I am in front of the students.

18. Physical science must be taught by doing practical work in class, for effective learning of the subject.

19. As a student, I did not do any practical work in class and so I do not see any point in forcing my students to do practical work when I teach physical science today.

20. Importance need not be given to practical work in class in teaching physical science.

THANK YOU FOR YOUR CO-OPERATION

=KSR=================================9=2=94

APPENDIX IX

SUMMARY OF TEACHER RESPONSES (START, T-QR-C)

NUMBER	STRONGLY AGREE	AGREE	DISAGREE	STRONGLY DISAGREE
1	6	2	0	0
2	0	4	3	1
3	3	3	2	0
4	1	5	2	0
5	1	5	2	0
6	0	0	5	3
7	3	5	0	0
8	0	2	5	1
9	0	4	4	0
10	0	0	2	6
11	0	0	3	5
12	0	0	5	3
13	0	2	6	0
14	0	0	5	3
15	0	3	5	0
16	2	2	2	2
17	0	0	6	2
18	4	4	0	0
19	0	0	4	4
20	0	0	4	4

APPENDIX X

SUMMARY OF TEACHER RESPONSES (END, T-QR-E)

NUMBER	STRONGLY AGREE	AGREE	DISAGREE	STRONGLY DISAGREE
1	5	3	0	0
2	0	4	3	1
3	0	0	7	1
4	0	3	4	1
5	6	2	0	0
6	0	0	2	6
7	3	5	0	0
8	1	2	5	0
9	1	5	2	0
10	0	0	3	5
11	0	0	2	6
12	0	0	3	5
13	0	0	5	3
14	0	0	2	6
15	0	0	6	3
16	1	3	3	1
17	0	0	6	2
18	4	4	0	0
19	0	0	2	6
20	0	0	4	4

APPENDIX XI

SUMMARY OF STUDENT RESPONSES (START, S-QR-C) AS A PERCENTAGE

NO.	STRONGLY AGREE	AGREE	DISAGREE	STRONGLY DISAGREE
1	25	25	38	12
2	31	37	24	8
3	52	38	7	3
4	13	27	39	21
5	14	20	40	26
6	47	30	16	7
7	20	30	27	23
8	36	28	20	16
9	26	17	39	18
10	30	38	21	11
11	19	17	30	34
12	34	39	19	8
13	30	42	16	12
14	33	35	16	16
15	20	31	34	15
16	33	37	21	9
17	10	23	28	19
18	15	14	40	31
19	16	7	30	47
20	12	36	31	21

APPENDIX XII

SUMMARY OF STUDENT RESPONSES (END, S-QR-E) AS A PERCENTAGE

NO.	STRONGLY AGREE	AGREE	DISAGREE	STRONGLY DISAGREE
1	49	21	22	8
2	9	20	36	35
3	22	21	38	19
4	12	21	48	19
5	35	50	11	4
6	35	42	8	15
7	26	33	21	20
8	56	33	6	5
9	54	29	9	8
10	8	24	43	25
11	13	18	39	30
12	14	20	36	30
13	25	29	26	20
14	11	20	31	38
15	22	26	39	13
16	22	13	26	39
17	5	17	44	34
18	34	33	21	12
19	9	21	35	35
20	21	20	35	24

APPENDIX XIII

STUDENT ATTITUDE QUESTIONNAIRE (S-QR)

NOTE:

* This questionnaire is NOT a test.
* This is given to you to find out ways of improving the teaching of physical science in schools in Venda.
* You may write your answers without fear of being penalised for giving your true feelings. (As such, you need not write your name on the answer sheet.)
* Please give your frank answer to the statements in this questionnaire.

INSTRUCTIONS:

The answers to the statements in this questionnaire should be marked on the special answer sheet provided in the relevant column for each statement as to whether you strongly agree, agree, disagree, or strongly disagree as the case may be, with each of the statement by placing an` X' in the relevant column of the answer sheet.

1. Physical science is an interesting subject.
2. The best way to learn physical science is to follow closely the recommended textbook.
3. The experiments in physical science can only be done satisfactorily in a properly-equipped school laboratory.
4. The teacher may not be able to complete the syllabus in physical science if he starts doing experiments in class.
5. Some practicals in physical science are simple enough to be done easily in the classroom.
6. The more difficult practicals in physical science are the ones that should be done to help us learn physical science properly.
7. My teacher would have done some experiments in physical science in class, had there been science equipment in my school.

8. I will understand physical science better if my teacher does experiments in class.

9. The experiments done by my teacher in class helped me in better understanding of physical science.

10. The extra effort and energy spent by my teacher in doing practicals in physical science in class is not worth it.

11. I do not think that the amount of money spent in doing practicals in class in learning physical science is worth it.

12. I like to watch the teacher do the experiments as it is troublesome to do them myself.

13. If I have science textbooks, I will understand physical science even if I do not do any practicals in class.

14. Doing experiment in class is not useful in learning physical science as the results of such experiments are usually not accurate.

15. We could benefit more, if the time spent in the preparation for practical work by the teacher is devoted to teach us more physical science content in class.

16. Experiments are only useful if they give the same answer as in the textbook.

17. While doing experiments, many things can go wrong and therefore much cannot be learnt from practical work in physical science.

18. I learn many things when I do experiments in physical science even if I do not get accurate results.

19. I hate to do science projects as I am not good at doing things with my hand.

20. Importance need not be given to doing practicals in class in the learning of physical science.

THANK YOU FOR YOUR PARTICIPATION IN THIS PROJECT
BEST OF LUCK IN YOUR STUDIES

=KSR===Feb=1994=

APPENDIX XIV

INSERVICE WORKSHOP FOR PHYSICAL SCIENCE TEACHERS - 1993/94

END OF COURSE EVALUATION QUESTIONNAIRE

* This questionnaire is to get a feedback on the usefulness of the in-service workshops held so far, so as to enable me to evaluate the effectiveness of the course and to improve the workshops in future.

* Please feel free to give your true feelings regarding these workshops.

* The information provided by you will be used for the purpose of evaluation and improvement of this course in future.

* Please note that your name is not required for this questionnaire.

INSTRUCTIONS:

* Please answer the questions in this questionnaire in the space provided for each question.

* Any additional comments can be done at the end or on the reverse of the questionnaire sheet.

1. Were you happy to have been selected for this workshop? Motivate your answer.

2. Was the workshop useful to you as a teacher? Give the reasons why?

3. Was the content covered too little, just right or too ambitious?

4. Was the handout given sufficiently clear and self explanatory? If not what should be done to improve it?

5. Were the different workshops held useful enough for you to use the experience from them in class? If not, what should be done to improve it?

6. Was the concept of improvisation new to you or have you been using this in your teaching of sciences?

7. Do you think this method has its advantages and disadvantages?

List the advantages:	List the disadvantages:
1	1
2	2
3	3
4	4

8. Using the list you made to question 7 above, do you think that this method of teaching science in schools in Venda has its own advantage over the disadvantages? Motivate your answer.

9. Would you like to attend further workshops in future? Why?
Give the areas or topics that you would like us to cover in future workshops.

10. What is your overall evaluation of this workshop? (Good/average/poor)

11. Is the duration of the workshop satisfactory?

12. How would you like to receive communication regarding workshops in the future?

13. Did you hear the radio announcement regarding this workshop?

14. Would you like to follow a formal training course in the teaching of physical science/mathematics/biology at the university with an idea of obtaining a diploma or certificate?

15. Having followed this course, do you think that you are in a better position to motivate and guide your science students to take part in activities like Expo for young scientists to enable them to bring out their hidden talents?

Your answers and suggestions will be taken into consiideration in future plans for further workshops. For the present, I hope you will be in a position to use the equipment supplied in your school to perform the experiments in your science classes and make the teaching of science meaningful to the students and look after the equipment to be used in future years to come. Best of luck in your teaching of science using these and other improvised equipment.

I would also like to take this opportunity to thank you for your valuable participation in this project and I enjoyed working with you.

A further questionnaire will be sent to you to be administered to your students after they have been exposed to the apparatus suppiled, in order to find out the change your students have undergone as a result of implementing this method in the teaching of science in your school. Please have them sent back to me by post or in person.

Best wishes to you in your teaching of sciences.

=K=S=R==25=03=94=